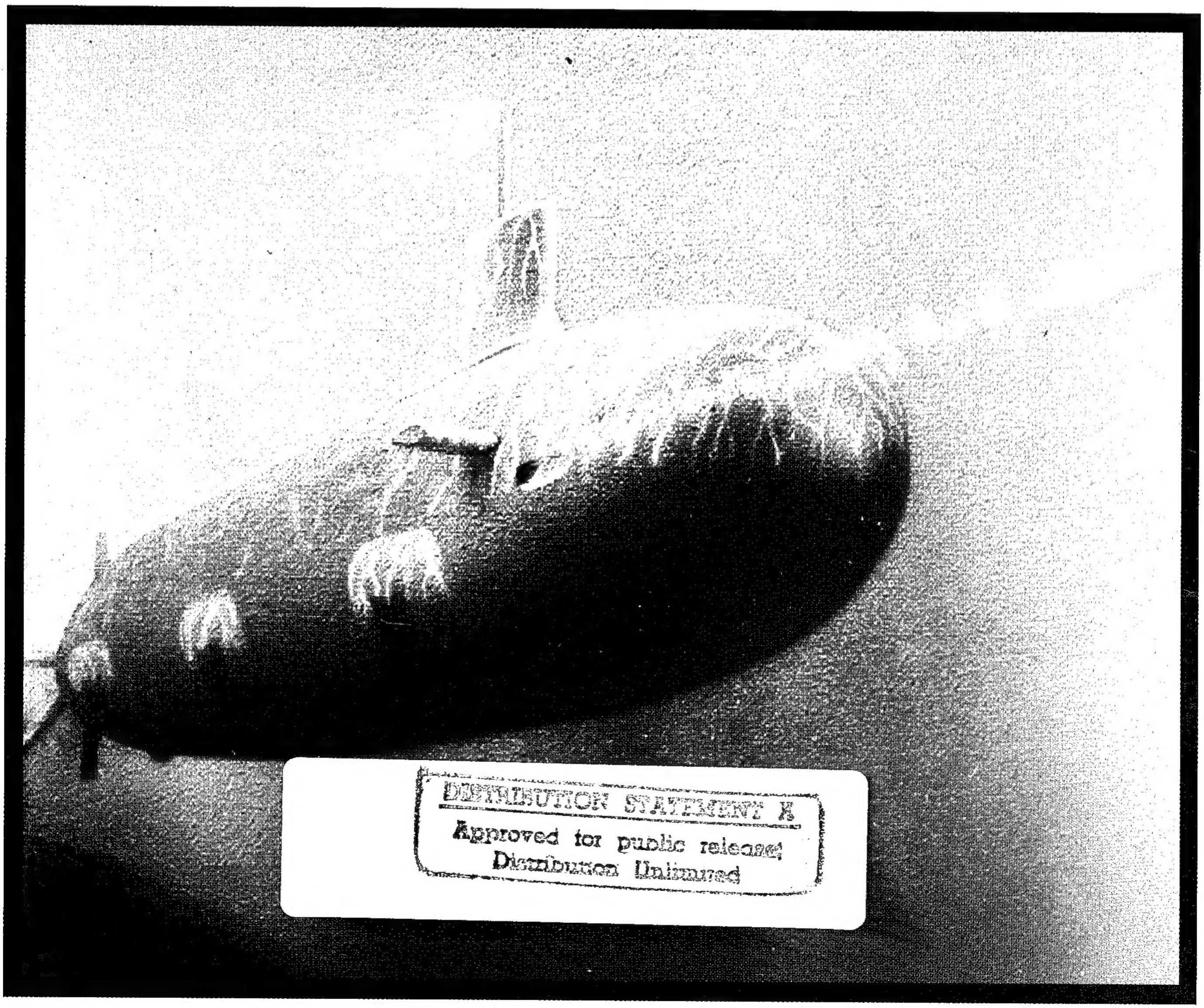
REQUEST FOR LETTER OF AUTHORIZATION FOR THE INCIDENTAL TAKE OF MARINE MAMMALS ASSOCIATED WITH SHOCK TESTING THE SEAWOLF SUBMARINE

JUNE 1996

DEPARTMENT OF THE NAVY



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EXECUTIVE SUMMARY

This document is a Request for Letter of Authorization for the incidental take of marine mammals associated with shock testing of the SEAWOLF submarine off Mayport, Florida or Norfolk, Virginia. The incidental take request is submitted in accordance with Section 101(a)(5) of the Marine Mammal Protection Act. A Draft Environmental Impact Statement (DEIS) has been prepared separately for the proposed shock testing (Department of the Navy, 1996).

PROPOSED ACTION

The SEAWOLF would be subjected to a series of five 4,536 kg (10,000 lb) explosive charge detonations of incrementally increasing intensity sometime between 1 April and 30 September 1997. If the Mayport area is selected, the shock tests would be conducted between 1 May and 30 September 1997 to minimize risk to sea turtles, which are more abundant at the Mayport area during April. The shock tests would be conducted at a rate of one detonation per week to allow time to perform detailed inspections of the submarine's systems prior to the submarine experiencing the next level of shock intensity.

PURPOSE AND NEED

The USS SEAWOLF is the first of a new class of submarines being acquired by the Navy. The class is expected to consist of three submarines, with the second currently under construction. SEAWOLF class submarines will be the largest and most capable fast attack submarines in the fleet. Features include reduced acoustic and electromagnetic signatures, improved speed, greater maximum operating depth, greater ordnance capacity, and other technological improvements reflecting the state-of-the-art in submarine design.

The purpose of this project is to shock test the SEAWOLF submarine so that the resultant data can be used to assess the survivability of the submarine. This project is needed because computer modeling and component testing on machines or in surrogates does not provide adequate information to assess the survivability of the submarine in accordance with Section 2366, Title 10, United States Code (10 USC 2366). Only by testing the submarine manned with the appropriate systems operating can the shock response of the entire ship, including the interaction of ship systems and components, be obtained and an adequate assessment of the survivability of the submarine be determined in accordance with 10 USC 2366. Shock tests have proven their value as recently as the Persian Gulf War when ships were able to survive battle damage and continue their mission because of ship design, crew training, and survivability lessons learned during previous shock tests.

GEOGRAPHICAL REGION

In the alternatives analysis presented in the DEIS, the Navy concluded that only two areas meet operational requirements for the proposed shock testing: Mayport, Florida and Norfolk, Virginia. The requirements include an east coast location within 185 km

(100 nmi) of a naval station support facility and a submarine repair facility, a water depth of 152 m (500 ft), calm seas and good visibility, and little or no shipping traffic.

The final, specific site for shock testing would not be selected until 2 to 3 days before the test based on marine mammal and turtle surveys (see Section 4). Three weeks prior to the shock test, a single aerial survey would be conducted over the selected area (i.e., Mayport or Norfolk) to identify a single primary test site and two secondary test sites based on the lowest relative abundance of marine mammals and turtles. Two to three days prior to each detonation, an aerial survey would be conducted at the primary and secondary sites, and a final test site would be selected on the basis of scarcity of marine mammals and turtles. This would ensure that the final test site would be selected where shock testing poses the least risk to the marine environment.

The Mayport area is located on the continental shelf offshore of Georgia and northeast Florida, along the 152 m (500 ft) depth contour from about 31°15'N to 29°32'N latitude. Naval facilities to support the shock test are located at Naval Station Mayport near Jacksonville, Florida and Naval Submarine Base Kings Bay, Georgia.

The Norfolk area is located on the continental shelf offshore of Virginia and North Carolina, along the 152 m (500 ft) depth contour from about 36°57'N to 35°45'N latitude. Naval facilities to support the shock test are located at Naval Station Norfolk.

MARINE MAMMAL PRESENCE AND DISTRIBUTION

Marine mammal presence and distribution at the Mayport and Norfolk areas can be described based on historical data and 1995 aerial surveys. Observed densities estimated from 1995 aerial surveys were adjusted to take into account submerged individuals and those that may have been on the surface but undetected.

Mayport Area

Based on historical records and aerial survey results, 29 marine mammal species may occur at the Mayport site, including 7 baleen whales and 22 toothed whales and dolphins. Six of these are considered likely to occur (presence probable): Atlantic spotted dolphin, bottlenose dolphin, pantropical spotted dolphin, Risso's dolphin, spinner dolphin, and pilot whale. The other 23 species could occur in the area but are not especially likely to be found there (presence possible).

A total of 1,303 individuals representing at least seven species of marine mammals were seen at the Mayport site during the 1995 aerial surveys. Based on all six surveys, observed mean densities of marine mammals were about 7 individuals/100 km^2, and adjusted mean densities were about 41 individuals/100 km^2. Because there would be no shock testing in April at Mayport, mean densities for Mayport were also calculated for the May-September period (i.e., excluding April). For the May-September period, observed mean densities were about 6 individuals/100 km^2 and adjusted mean densities were about 32 individuals/100 km^2. The most abundant species were pantropical spotted dolphin, bottlenose dolphin, Risso's dolphin, Atlantic spotted dolphin, and spinner dolphin.

Six of the marine mammals potentially occurring at Mayport are listed as endangered as defined by the Endangered Species Act of 1973. These are the blue whale, fin whale,

humpback whale, northern right whale, sei whale, and sperm whale. However, none are listed as "presence probable," and the only endangered species seen during 1995 aerial surveys was the sperm whale (two individuals were sighted). Blue, fin, humpback, and northern right whales generally inhabit northern feeding grounds during the period proposed for shock testing and would not be expected to occur in the area during this time.

Norfolk Area

Based on historical records, 34 marine mammal species may occur at the Norfolk site, including 7 baleen whales, 26 toothed whales and dolphins, and 1 seal. Of these, 11 species are considered likely to occur (presence probable): fin whale, minke whale, sei whale, humpback whale, pilot whale, Atlantic spotted dolphin, bottlenose dolphin, pantropical spotted dolphin, common dolphin, Risso's dolphin, and spinner dolphin. The other 23 species could occur in the area but are not especially likely to be found there (presence possible).

A total of 4,438 individuals representing at least 14 species of marine mammals were seen at the Norfolk site during the 1995 aerial surveys. Observed densities of marine mammals (all species combined) averaged about 50 individuals/100 km^2, and adjusted densities averaged 280 individuals/100 km^2. About one-third of the mammals observed were pilot whales. Other abundant species were Atlantic spotted dolphin, bottlenose dolphin, pantropical spotted dolphin, common dolphin, and Risso's dolphin.

Six of the marine mammals potentially occurring at Norfolk are listed as endangered as defined by the Endangered Species Act of 1973. These are the blue whale, fin whale, humpback whale, northern right whale, sei whale, and sperm whale. Four of these species (fin whale, humpback whale, sei whale, and sperm whale) were observed during April through July surveys. Fin whales were the most common large whale seen. No endangered species were seen during surveys after July, when it is presumed that these animals had migrated to northern feeding grounds.

MITIGATION

The proposed action includes mitigation that would minimize risk to marine mammals. The Navy would (1) select an operationally suitable test site which poses the least risk to the marine environment; (2) effectively monitor the site prior to each detonation to ensure that it is free of marine mammals, turtles, large schools of fish, and flocks of seabirds; and (3) determine the effectiveness of the mitigation efforts by using a Marine Animal Recovery Team (MART) and aerial observers to survey the site for injured or dead animals after each detonation. If post-detonation monitoring showed that marine mammals or turtles were killed or injured as a result of a detonation, testing would be halted until procedures for subsequent detonations could be reviewed and changed as necessary.

The concept of a safety range is integral to the mitigation plan. The safety range radius of 3.79 km (2.05 nmi) was calculated using information on eardrum rupture, which is the most conservative measure of non-lethal injury discussed in Appendix C. The maximum predicted horizontal distance for a 10% probability of eardrum rupture for a marine mammal is 3.79 km (2.05 nmi). A buffer zone of 1.8 km (0.95 nmi) was added to

ensure that no marine mammal could enter the safety range while monitoring aircraft were completing their pre-detonation surveys. The safety range radius is more than twice the maximum range for lethality.

The proposed mitigation program is similar to the one used successfully during the shock trial of the USS JOHN PAUL JONES, which involved detonation of two 4,536 kg (10,000 lb) charges off the California coast. There were were no marine mammal deaths or injuries from those detonations, despite marine mammal densities that were about 3 times higher than at the Norfolk area and about 25 times higher than at the Mayport area. In addition, based on the patchy distribution of marine mammals at the Mayport and Norfolk areas, the Navy expects to be able to select a specific test site with few, if any, marine mammals present.

POTENTIAL INCIDENTAL TAKE

Potential impacts to marine mammals from shock testing include lethal and non-lethal injury, as well as acoustic discomfort (harassment). It is very unlikely that marine mammals would be affected by exposure to the chemical by-products of the detonations, and no permanent alteration of marine mammal habitat would occur.

Extensive modeling of the potential impact of shock test detonations on marine mammals has been completed (Appendices C and D). Several possible criteria for lethal and injurious take and harassment were evaluated, and the most conservative criterion was chosen in each case. For lethal take, the criterion is the onset of extensive lung injury for a small marine mammal. For injurious take, the criterion is a 10% probability of eardrum rupture for an animal at the sea bottom. For harassment, an acoustic discomfort criterion has been developed. **Table ES-1** summarizes the maximum range and corresponding area for each take category.

Because the safety range exceeds the maximum ranges for mortality and injury, marine mammals could be killed or injured only if they were present within the safety range but not detected during pre-detonation monitoring. Based on a series of conservative assumptions designed to overestimate potential impacts, estimates of lethal and injurious incidental take and harassment were calculated for Mayport (**Table ES-2**) and Norfolk (**Table ES-3**). Each table provides information for incidental take with and without mitigation, but shock testing would only be conducted with mitigation. A summary is presented in **Table ES-4**.

Mayport Area

Table ES-2 summarizes the incidental take calculations for the Mayport area. Estimated totals for five detonations "with mitigation" are 1 lethal take, 5 injurious takes, and 570 harassment takes. It is very unlikely that even one individual would be killed or injured by a single detonation at the Mayport area. Species most likely to be affected at Mayport are pantropical spotted dolphin, Risso's dolphin, and Atlantic spotted dolphin.

The only endangered marine mammal species potentially killed or injured at Mayport is the sperm whale. The estimated numbers are 0.01 or less per detonation for both mortality and injury; totals for five detonations are 0.01 mortalities and 0.05 injuries.

Table ES-1. Maximum ranges and corresponding areas for various categories of incidental take. Ranges are based on calculations in Appendices C and D as indicated. Areas were calculated using πr^2, where r = maximum range.

Take Category and Criterion	Maximum Range		Area Within Range	
	m (ft)	km (nmi)	Original Calculation km^2 (nmi^2)	After Subtracting Inner Range(s)[a] km^2 (nmi^2)
Lethal Take:				
Extensive lung hemorrhage (1% mortality) (Appendix C)	1,524 m (5,000 ft)	1.52 km (0.82 nmi)	7.30 km^2 (2.13 nmi^2)	7.30 km^2 (2.13 nmi^2)
Injurious Take:				
10% eardrum rupture at 152 m (500 ft) (Appendix C)	3,792 m (12,440 ft)	3.79 km (2.05 nmi)	45.16 km^2 (13.15 nmi^2)	37.86 km^2 (11.02 nmi^2)
Harassment:				
Acoustic discomfort (Appendix D)	11,111 m (36,456 ft)	11.11 km (6.00 nmi)	387.86 km^2 (112.93 nmi^2)	342.70 km^2 (99.78 nmi^2)

[a] Injury and harassment areas were corrected to avoid double-counting different take categories. For example, if an animal were killed, it should not also be counted as injured. The area of the lethal range was subtracted from the area of the injury range. Similarly, the uncorrected area of the injury range was subtracted from the harassment range.

Table ES-2. Potential lethal and injurious take and harassment of marine mammals at the Mayport area, with mitigation. Numbers are given to two decimal places to indicate relative risk to various species; totals are rounded up at the end of the table. Species historically present in the region but not seen at Mayport during 1995 aerial surveys (indicated by * next to the species name) are assigned totals of 0 individuals for lethal and injurious take and 1 individual for harassment.

Species	MAYPORT AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment
BALEEN WHALES			
* Blue whale (E)	0	0	1
* Bryde's whale	0	0	1
* Fin whale (E)	0	0	1
* Humpback whale (E)	0	0	1
* Minke whale	0	0	1
* Northern right whale (E)	0	0	1
* Sei whale (E)	0	0	1
TOOTHED WHALES AND DOLPHINS			
Atlantic spotted dolphin	0.08	0.40	49.73
Bottlenose dolphin	0.08	0.40	50.37
Bottlenose/Atlantic spotted dolphin	0.03	0.14	16.79
Clymene/spinner/striped dolphin	0.01	0.05	12.27
Pantropical spotted dolphin	0.23	1.19	147.89
Risso's dolphin	0.17	0.90	113.02
Sperm whale (E)	0.01	0.05	2.58
Spinner dolphin	0.02	0.13	32.29
Unidentified dolphin	0.19	0.97	121.42
* Blainville's beaked whale	0	0	1
* Clymene dolphin	0	0	1
* Common dolphin	0	0	1
* Cuvier's beaked whale	0	0	1
* Dwarf sperm whale	0	0	1
* False killer whale	0	0	1
* Fraser's dolphin	0	0	1
* Gervais' beaked whale	0	0	1
* Killer whale	0	0	1
* Melon-headed whale	0	0	1
* Pilot whale	0	0	1
* Pygmy killer whale	0	0	1
* Pygmy sperm whale	0	0	1
* Rough-toothed dolphin	0	0	1
* Striped dolphin	0	0	1
* True's beaked whale	0	0	1
TOTAL (rounded up, exact value in parentheses)	**1** (0.82)	**5** (4.23)	**570** (569.36)

(E) = endangered species. NA = not applicable. * = species historically present in the region but not seen at the Mayport area during 1995 aerial surveys.

Table ES-3. Potential lethal and injurious take and harassment of marine mammals at the Norfolk area, with mitigation. Numbers are given to two decimal places to indicate relative risk to various species; totals are rounded up at the end of the table. Species historically present in the region but not seen at Norfolk during 1995 aerial surveys (indicated by * next to the species name) are assigned totals of 0 individuals for lethal and injurious take and 1 individual for harassment.

Species	NORFOLK AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment
BALEEN WHALES			
Fin whale (E)	0.12	0.60	49.65
Humpback whale (E)	<0.01	0.01	1.08
Minke whale	0.05	0.27	4.32
Sei whale (E)	0.01	0.03	2.16
Sei or Bryde's whale	<0.01	0.01	1.08
Unidentified *Balaenoptera* sp.	0.03	0.16	12.95
Unidentified baleen whale	0.01	0.05	4.32
* Blue whale (E)	0	0	1
* Bryde's whale	0	0	1
* Northern right whale (E)	0	0	1
TOOTHED WHALES AND DOLPHINS			
Atlantic spotted dolphin	1.37	7.13	889.34
Bottlenose dolphin	0.86	4.44	554.76
Bottlenose/Atlantic spotted dolphin	0.11	0.55	69.07
Clymene/spinner/striped dolphin	0.20	1.06	264.43
Common dolphin	0.52	2.68	334.58
Cuvier's beaked whale	0.05	0.27	4.32
Pantropical spotted dolphin	0.72	3.76	469.49
Pilot whale	2.29	11.90	1485.11
Risso's dolphin	0.20	1.03	128.44
Sperm whale (E)	0.04	0.18	8.63
Spinner dolphin	0.05	0.27	66.92
Striped dolphin	0.02	0.10	25.90
Unidentified dolphin	0.64	3.34	416.61
Unidentified small whale	0.01	0.04	5.40
* Atlantic white-sided dolphin	0	0	1
* Blainville's beaked whale	0	0	1
* Clymene dolphin	0	0	1
* Dwarf sperm whale	0	0	1
* False killer whale	0	0	1
* Fraser's dolphin	0	0	1
* Gervais' beaked whale	0	0	1
* Harbor porpoise	0	0	1
* Killer whale	0	0	1
* Melon-headed whale	0	0	1
* Northern bottlenose whale	0	0	1
* Pygmy killer whale	0	0	1
* Pygmy sperm whale	0	0	1
* Rough-toothed dolphin	0	0	1
* Sowerby's beaked whale	0	0	1
* True's beaked whale	0	0	1
PINNIPEDS			
* Harbor seal	0	0	1
TOTAL (rounded up, exact value in parentheses)	**8** (7.30)	**38** (37.88)	**4,819** (4818.55)

(E) = endangered species. NA = not applicable.
* = species historically present in the region but not seen at the Norfolk area during 1995 aerial surveys.

Table ES-4. Summary and comparison of Mayport and Norfolk areas with respect to potential incidental take and mitigation effectiveness. Values are for five detonations, with mitigation. The proposed action would be conducted at only one location (Mayport or Norfolk).

Incidental Take Category	Description	Mayport	Norfolk
Lethal	Number of individuals potentially killed from 5 detonations	1	8
Injurious	Number of individuals potentially injured from 5 detonations	5	38
Harassment	Number of individuals potentially experiencing acoustic discomfort from 5 detonations	570	4,819
Mitigation effectiveness for lethal and injurious take	Percentage of individuals present within safety range that would be detected by combination of aerial, surface, and passive acoustic monitoring	93%	93%

Therefore, it is highly unlikely that any sperm whales would be killed or injured by the five detonations. Sperm whales produce distinctive low-frequency clicked vocalizations and are very likely to be detected (if present) using the passive acoustic monitoring system described in Section 4. The other endangered marine mammals (blue, fin, humpback, sei, and northern right whales) are baleen whales which generally inhabit northern feeding grounds during the period proposed for shock testing and which were never observed off Mayport during the 1995 aerial census efforts. Therefore, it is very unlikely that any would be killed or injured by the proposed action.

Norfolk Area

Table ES-3 summarizes the incidental take calculations for the Norfolk area. Estimated totals for five detonations "with mitigation" are 8 lethal takes, 38 injurious takes, and 4,819 harassment takes. Species that could have a total of more than one individual killed as a result of five detonations are pilot whale and Atlantic spotted dolphin. Species that could have more than one individual injured as a result of five detonations are pilot whale, Atlantic spotted dolphin, bottlenose dolphin, pantropical spotted dolphin, and common dolphin.

In contrast to Mayport, several endangered whale species could be affected at the Norfolk area. The highest numbers are for fin whale, which was the most abundant baleen whale at the area during 1995 aerial surveys. It is unlikely that a fin whale would be killed (0.12 individuals), but more likely that one would be injured (0.60 individuals). For the humpback, sei, and sperm whales, the lethal take estimates per detonation are 0.01 individuals or fewer, indicating it is very unlikely that individuals of these species would be killed. Two other endangered species, the blue whale and the northern right whale, generally inhabit northern feeding grounds during the period proposed for shock testing and were never observed off Norfolk during the 1995 aerial census efforts; therefore, it is very unlikely that any would be killed or injured by the proposed action.

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LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
BRAC	Base Closure and Realignment
CETAP	Cetacean and Turtle Assessment Program
CL	Ceiling concentration
DEIS	Draft Environmental Impact Statement
EPA	Environmental Protection Agency
GPS	Global Positioning System
HBX	High Blast eXplosive
LFT&E	Live Fire Test & Evaluation
MART	Marine Animal Recovery Team
MMATS	Marine Mammal Acoustic Tracking System
MMPA	Marine Mammal Protection Act
NEPA	National Environmental Policy Act
NIOSH	National Institute for Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OPNAVINST	Chief of Naval Operations Instruction
OSHA	Occupational Safety and Health Administration
OTC	Officer in Tactical Command
PERSTEMPO	Personnel Tempo (Navy regulations)
PTS	Permanent threshold shift
STEL	Short-term exposure limit
TTS	Temporary threshold shift
USC	U.S. Code

1.0 INTRODUCTION

1.1 PROPOSED ACTION

This document is a Request for Letter of Authorization for the incidental take of marine mammals associated with shock testing of the SEAWOLF submarine off Mayport, Florida or Norfolk, Virginia. The submarine would be subjected to a series of five 4,536 kg (10,000 lb) explosive charge detonations of incrementally increasing intensity sometime between 1 April and 30 September 1997. If the Mayport area is selected, the shock tests would be conducted between 1 May and 30 September 1997 to minimize risk to sea turtles, which are more abundant at the Mayport area during April. The shock tests would be conducted at a rate of one detonation per week to allow time to perform detailed inspections of the submarine's systems prior to the submarine experiencing the next level of shock intensity. A Draft Environmental Impact Statement (DEIS) has been prepared separately for the proposed shock testing (Department of the Navy, 1996).

1.2 PURPOSE AND NEED

The USS SEAWOLF is the first of a new class of submarines being acquired by the Navy. The class is expected to consist of three submarines, with the second currently under construction. SEAWOLF class submarines will be the largest and most capable fast attack submarines in the fleet. Features include reduced acoustic and electromagnetic signatures, improved speed, greater maximum operating depth, greater ordnance capacity, and other technological improvements reflecting the state-of-the-art in submarine design.

In accordance with Section 2366, Title 10, United States Code (10 USC 2366), a covered system, such as a submarine, cannot proceed beyond initial production until realistic survivability testing of the system is completed. Realistic survivability testing means testing for the vulnerability of the system in combat by firing munitions likely to be encountered in combat with the system configured for combat. This testing is commonly referred to as "Live Fire Test & Evaluation" (LFT&E). The Navy has established a LFT&E program to complete the survivability testing of SEAWOLF Class submarines as required by 10 USC 2366. The SEAWOLF LFT&E program includes a shock test of the entire ship. A ship shock test is a series of underwater detonations that propagate a shock wave through a ship's hull under deliberate and controlled conditions. Shock tests simulate near misses from underwater explosions similar to those encountered in combat.

The purpose of this project is to shock test the SEAWOLF so that the resultant data can be used to assess the survivability of the submarine. This project is needed because computer modeling and component testing on machines or in surrogates does not provide adequate information to assess the survivability of the submarine. Only by testing the submarine manned with the appropriate systems operating can the shock response of the entire ship, including the interaction of ship systems and components, be obtained and an adequate assessment of the survivability of the ship be determined in accordance with 10 USC 2366. Shock tests have proven their value as recently as the Persian Gulf War when ships were able to survive battle damage and continue their

mission because of ship design, crew training, and survivability lessons learned during previous shock tests.

The SEAWOLF was christened in June 1995 and is expected to be delivered to the Navy in the summer of 1996. Sea trials will begin about three months before delivery to the Navy, and shakedown (operational) tests and trial operations will be conducted on the ship for about a year. Because of the long series of initial tests, shock testing cannot occur before April 1997. Shock testing must be completed before October when unfavorable weather conditions are more likely occur and prior to the ship's scheduled Post Shake Down Availability scheduled to begin after the shock test in 1997. During the Post Shake Down Availability, the ship will be thoroughly inspected prior to unrestricted fleet operations in 1998.

1.3 GEOGRAPHICAL REGION

In the alternatives analysis presented in the DEIS, the Navy concluded that only two areas meet operational requirements for the proposed shock testing: Mayport, Florida and Norfolk, Virginia (**Figure 1-1**). The requirements include an east coast location within 185 km (100 nmi) of a naval station support facility and a submarine repair facility, a water depth of 152 m (500 ft), calm seas and good visibility, and little or no shipping traffic.

The final specific site within the selected area for shock testing would not be selected until 2 to 3 days before the test based on marine mammal and turtle surveys (see Section 4). Three weeks prior to the shock test, a single aerial survey would be conducted over the selected area (i.e., Mayport or Norfolk) to identify a single primary test site and two secondary test sites based on the lowest relative abundance of marine mammals and turtles. Two to three days prior to each detonation, an aerial survey would be conducted at the primary and secondary sites, and a final test site would be selected on the basis of scarcity of marine mammals and turtles. This would ensure that the final test site would be selected where shock testing poses the least risk to the marine environment.

The Mayport area is located on the continental shelf offshore of Georgia and northeast Florida, along the 152 m (500 ft) depth contour from about 31°15'N to 29°32'N latitude (**Figure 1-2**). Naval facilities to support the shock test are located at Naval Station Mayport near Jacksonville, Florida and Naval Submarine Base Kings Bay, Georgia.

The Norfolk area is located on the continental shelf offshore of Virginia and North Carolina, along the 152 m (500 ft) depth contour from about 36°57'N to 35°45'N latitude (**Figure 1-3**). Naval facilities to support the shock test are located at Naval Station Norfolk.

1.4 DATES, DURATION, AND DESCRIPTION OF PROPOSED ACTIVITIES

Shock testing would occur sometime between 1 April and 30 September 1997. If the Mayport area is selected, the shock tests would be conducted between 1 May and 30 September 1997 to minimize risk to sea turtles, which are more abundant at the

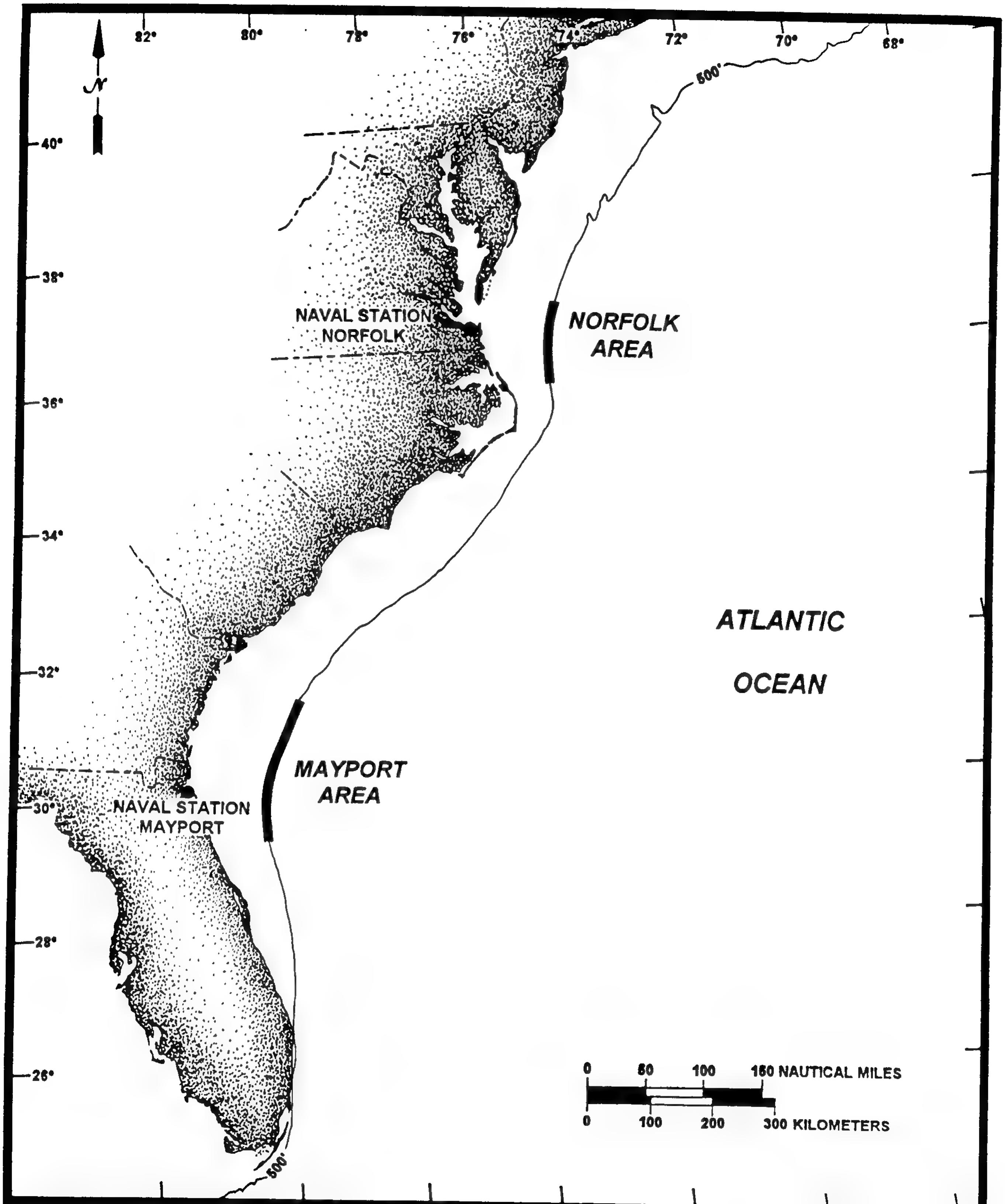


Figure 1-1. Location of the Mayport and Norfolk areas for SEAWOLF shock testing.

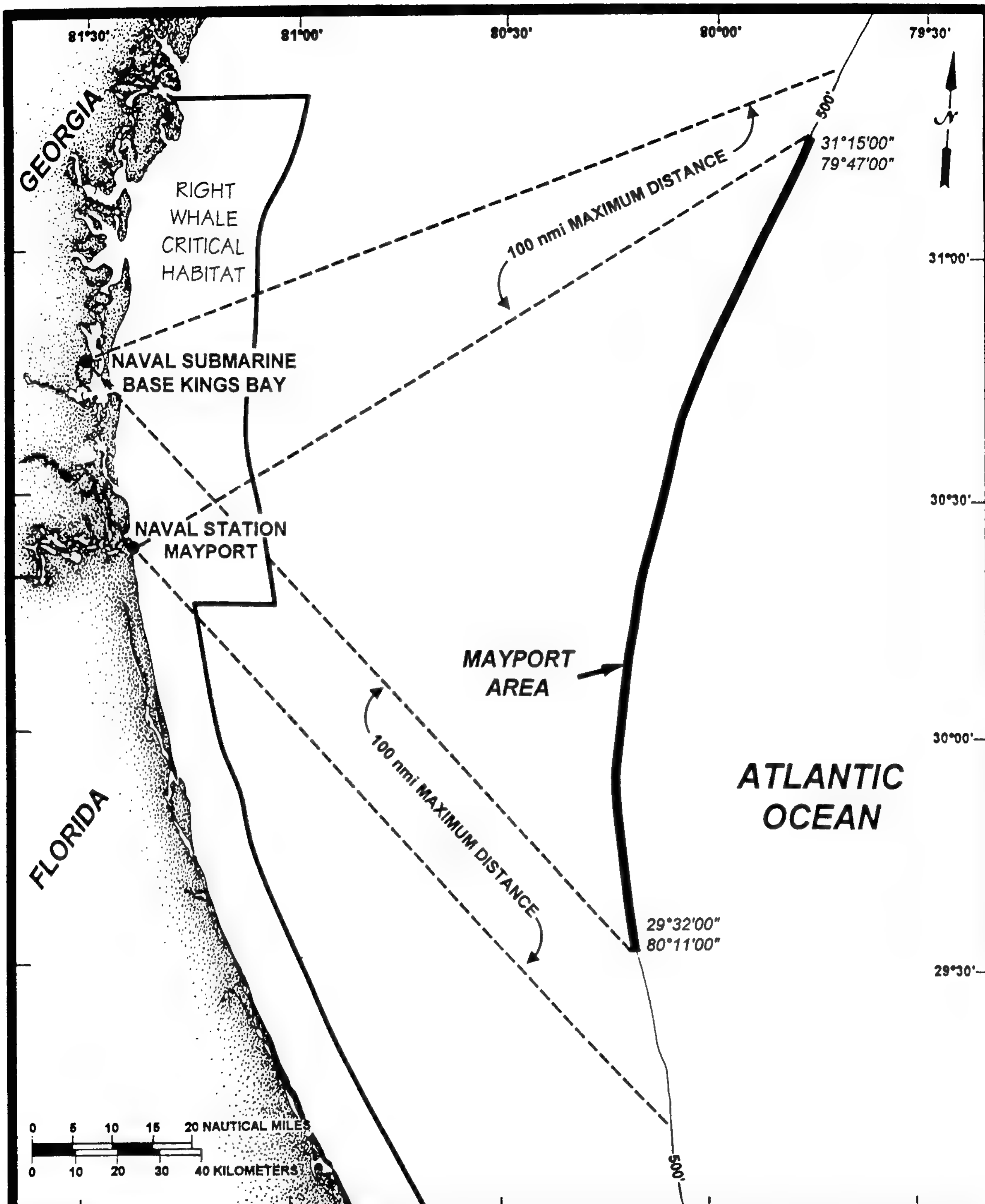


Figure 1-2. The Mayport area. The area includes all points along the 152 m (500 ft) depth contour within 185 km (100 nmi) of Naval Station Mayport and Naval Submarine Base Kings Bay.

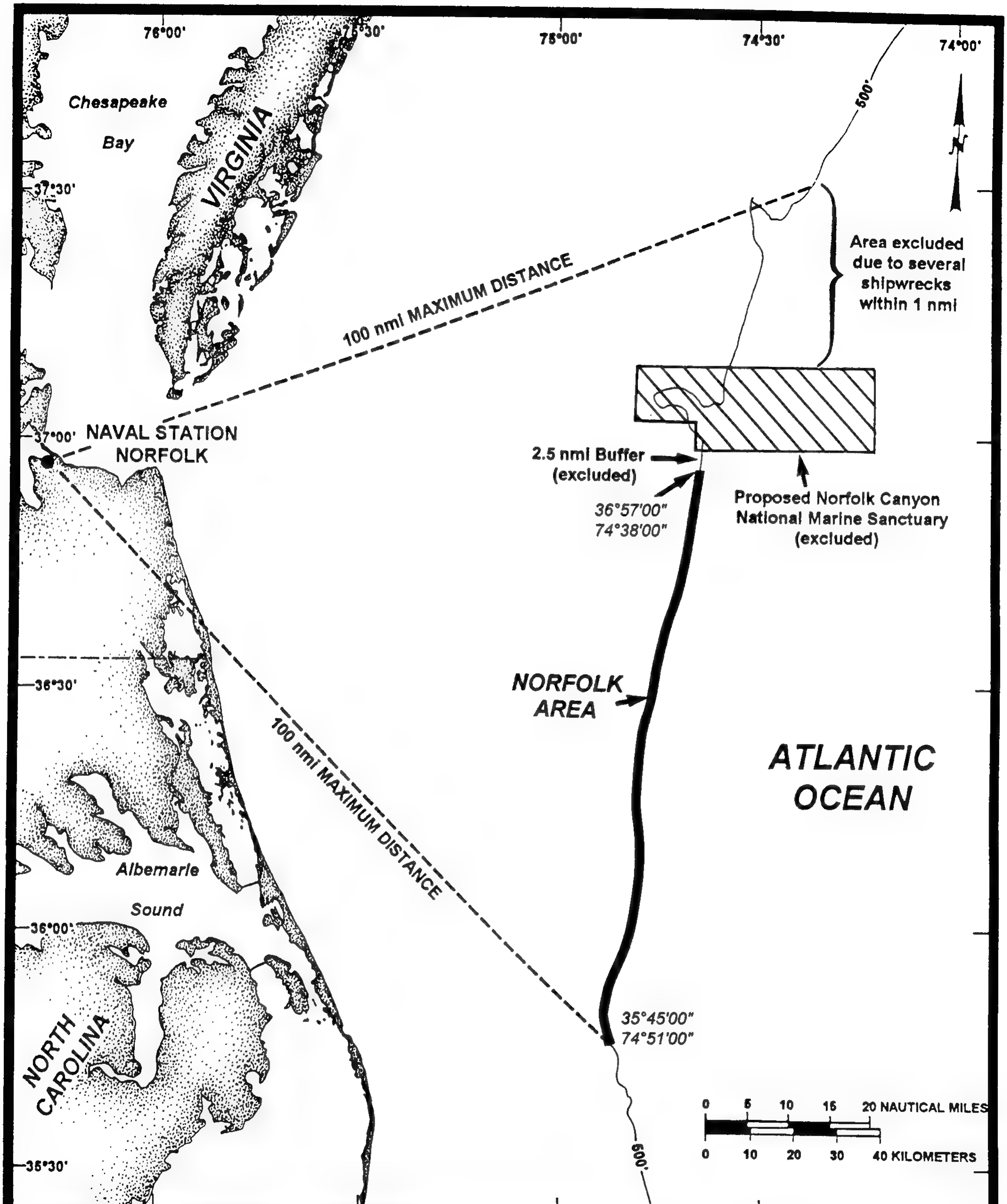


Figure 1-3. The Norfolk area. The area includes all points along the 152 km (500 ft) depth contour within 185 km (100 nmi) of Naval Station Norfolk, except the excluded areas indicated.

Mayport area during April. The shock tests would be conducted at a rate of one detonation per week to allow time to perform detailed inspections of the submarine's systems prior to the submarine experiencing the next level of shock intensity.

For shock testing, an operations vessel would moor in a water depth of 152 m (500 ft) at the test site. Test personnel would deploy a one-mile long test array (**Figure 1-4**). The array would consist of an explosive charge placed about 30 m (100 ft) below the water surface, marker buoys, instrumentation, connecting ropes, and the "gate", a small diameter rope that the submarine would break as it passes through the array. For each test, the submarine would submerge about 20 m (65 ft) below the water surface and navigate toward the marker buoys located on each side of the gate. As the submarine passes through the gate, the explosive would be detonated from the operations vessel. The submarine would then surface, and after an initial inspection for damage, travel back to the shore facility for post-test inspections and preparations for the next test. For each subsequent test, the gate would be moved closer to the explosive so the submarine experiences a more severe shock.

A conventional Navy explosive (High Blast eXplosive, HBX-1) would be used for each shock test. HBX-1 consists of the following components (by weight): cyclotrimethylene trinitramine - 39.32%; trinitrotoluene - 37.76%; aluminum powder - 17.10%; wax - 4.57%; and miscellaneous fillers - 1.25%. The charge would be held in a cylindrical steel container measuring 1.5 m (5 ft) in diameter by 1.7 m (5.6 ft) long with a total weight of 1,297 kg (2,860 lb) in air. The largest possible fragment from the explosion that would settle to the seafloor would be the top plate and crossbar which together weigh 204 kg (450 lb). After detonation, the test array would be recovered and floats and rigging debris would be removed.

The operational area for testing would be a 1.85 km (1 nmi) diameter zone centered on the explosive charge (**Figure 1-4**). An exclusion zone of 9.3 km (5 nmi) radius would be established around the test area to exclude all non-test ship, submarine, and aircraft traffic. This exclusion zone would be established for purposes of operational security and to allow an adequate distance for larger vessels to alter their course. Notices to Airmen and Mariners would be published in advance of each test. Traffic would be excluded from the area immediately prior to each shock test (i.e., 2 hours prior to detonation) and for several hours after each detonation to ensure the safety of non-essential (e.g., commercial, recreational) vessels and personnel and to facilitate pre- and post-detonation monitoring. The Navy would also contact the designated coordinator of the appropriate marine mammal stranding network (e.g., Northeast or Southeast Stranding Network) prior to each detonation; communications with stranding network personnel would be maintained throughout the SEAWOLF test period.

1.5 REGULATORY REQUIREMENTS

Section 101(a)(5) of the Marine Mammal Protection Act (MMPA; 16 USC 1361 et seq.) directs the Secretary of the Department of Commerce to allow, upon request, the incidental (but not intentional) taking of marine mammals by U.S. citizens who engage in a specified activity (exclusive of commercial fishing) within a specified geographical region if certain findings are made and regulations are issued. Permission may be granted by the Secretary for the incidental take of marine mammals if the taking will (1) have a

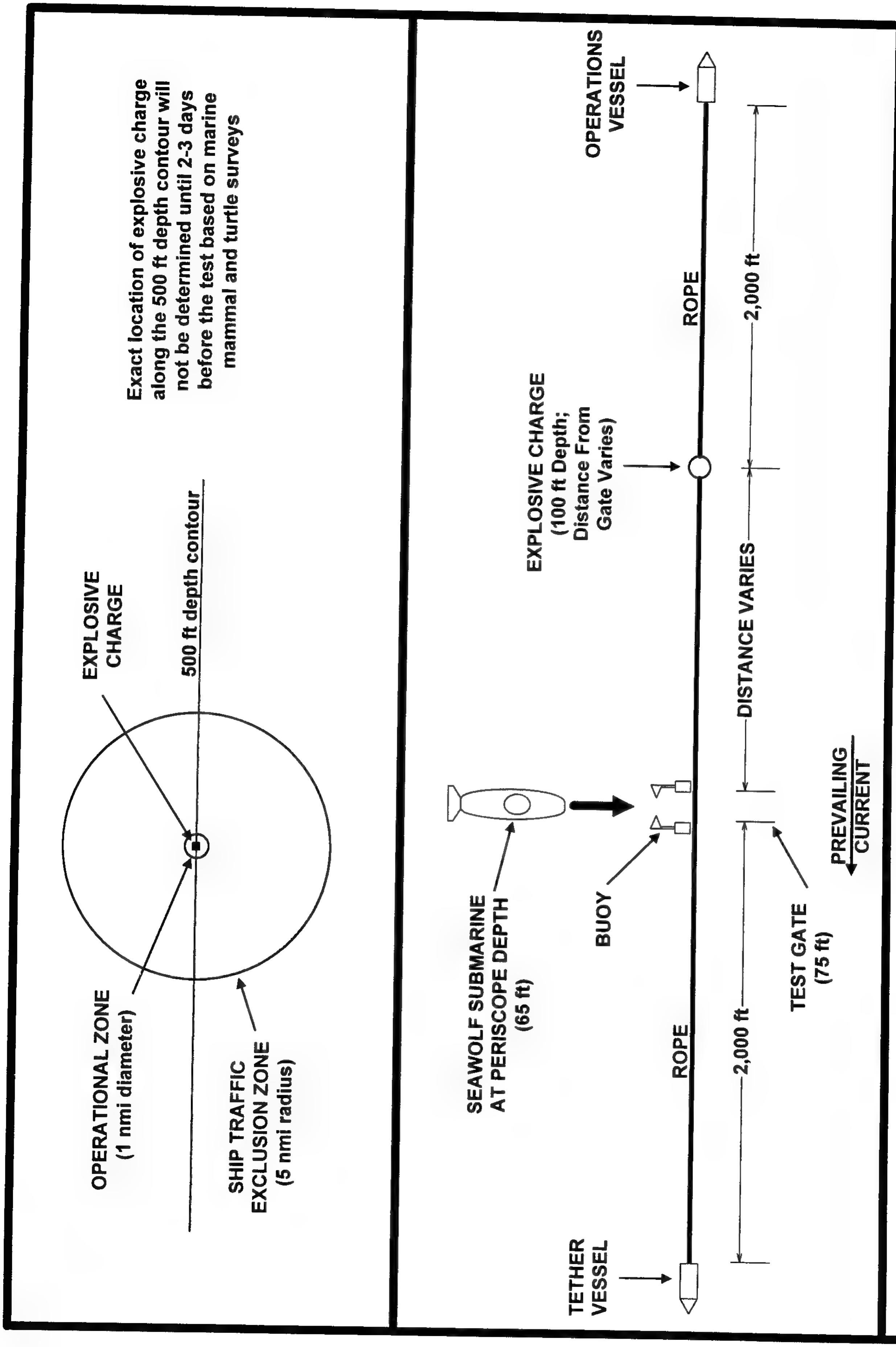


Figure 1-4. Test array, operational zone, and ship traffic exclusion zone for SEAWOLF shock testing.

negligible impact on the species or stock(s); and (2) not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses. Regulations must be prescribed setting forth the permissible methods of taking and the requirements pertaining to the monitoring and reporting of such taking.

Harassment, one of the forms of "take" as defined in the MMPA, is "any act of pursuit, torment, or annoyance which (a) has the potential to injure a marine mammal or marine mammal stock in the wild; or (b) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

In 1994, the MMPA was amended to, in part, establish expedited means by which an application for incidental take authorization (i.e., to incidentally take small numbers of marine mammals by harassment) could be processed. Subsection 101(a)(5)(d) establishes a 45-day time limit for application review, a 30-day public notice and comment period, and a final 45-day period during which the Department of Commerce, National Marine Fisheries Service (NMFS) acts (i.e., authorization or denial) on the application.

2.0 MARINE MAMMAL PRESENCE AND DISTRIBUTION

The following section considers listed (e.g., endangered, threatened) and nonlisted marine mammals which may occur in U.S. mid- and south Atlantic continental shelf and slope waters, based on existing literature sources, historical data, and recent field surveys. A listing of marine mammal species and their likelihood of occurrence within the Mayport and Norfolk areas, based on known distribution and historical sightings data, is provided in **Table 2-1** and summarized in Section 2.1. A summary of the marine mammals actually observed during six months of aerial surveys of the Mayport and Norfolk areas conducted in 1995 is presented in Section 2.2.

2.1 SPECIES, STATUS, AND SEASONAL DISTRIBUTION

2.1.1 Listed Marine Mammals

Baleen Whales

Blue whales (*Balaenoptera musculus*) range from the Arctic to at least mid-latitudes including the waters of the Gulf of Mexico. This species is pelagic, primarily found feeding north of the Gulf of St. Lawrence during spring and summer. It is considered as a very occasional species in waters off the eastern U.S. (Blaylock et al., 1995). Limited migration has been documented south to subtropical waters during fall and winter. This species feeds on krill and copepods, the abundance of which most likely controls migration in and out of polar areas. Mating and calving occurs in late fall and winter. Gestation lasts 10 to 11 months. Calves are born every 2 to 3 years. Blue whales are usually seen solitary or in groups of two or three individuals. Existing data are insufficient for stock differentiation and population estimates in the Atlantic (Blaylock et al., 1995).

Fin whales (*Balaenoptera physalus*) range from the Arctic to the Greater Antilles, including the Gulf of Mexico. They are usually found inshore of the 2,000-m (6,562-ft) contour. This species occurs widely in the middle Atlantic throughout the year, with concentrations from Cape Cod north in summer and from Cape Cod south in winter. This species is frequently found along the New England coast from spring to fall in areas of fish concentration. It is thought that fin whales migrate north nearshore along the coast during spring and south offshore during winter. This species feeds on krill, planktonic crustaceans, and schooling fish such as herring and capelin. It is believed that fin whales breed in the middle Atlantic, with mating and calving occurring from November to March. Gestation lasts about 1 year and calves are suckled for 7 months. Fin whales off the eastern U.S. to Canada constitute a single stock (Blaylock et al., 1995). The minimum population estimate for this species in the western Atlantic was 1,704 individuals, based on a 1991-92 shipboard survey (Blaylock et al., 1995).

Humpback whales (*Megaptera novaeangliae*) range from the Arctic to the West Indies, including the Gulf of Mexico. They are found in middle Atlantic shallow coastal waters during spring and in waters around Cape Cod to Iceland during late spring to fall. During summer there are at least five geographically distinct feeding aggregations in the northern Atlantic. Generally, their distribution has been largely correlated to prey species

Table 2-1. Status and historical presence of marine mammals potentially occurring at the Mayport and Norfolk areas.

Common and Scientific Name	Status[a]	Historical Presence[b]	
		Mayport	Norfolk
BALEEN WHALES (Mysticetes)			
Blue whale (*Balaenoptera musculus*)	E	+	+
Bryde's whale (*Balaenoptera edeni*)	–	+	+
Fin whale (*Balaenoptera physalus*)	E	+	++
Humpback whale (*Megaptera novaeangliae*)	E	+	++
Minke whale (*Balaenoptera acutorostrata*)	–	+	++
Northern right whale (*Eubalaena glacialis*)	E	+	+
Sei whale (*Balaenoptera borealis*)	E	+	++
TOOTHED WHALES AND DOLPHINS (Odontocetes)			
Atlantic spotted dolphin (*Stenella frontalis*)	–	++	++
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	–	–	+
Blainville's beaked whale (*Mesoplodon densirostris*)	–	+	+
Bottlenose dolphin (*Tursiops truncatus*)	PT	++	++
Clymene dolphin (*Stenella clymene*)	–	+	+
Common dolphin (*Delphinus delphis*)	–	+	++
Cuvier's beaked whale (*Ziphius cavirostris*)	–	+	+
Dwarf sperm whale (*Kogia simus*)	–	+	+
False killer whale (*Pseudorca crassidens*)	–	+	+
Fraser's dolphin (*Lagenodelphis hosei*)	–	+	+
Gervais' beaked whale (*Mesoplodon europaeus*)	–	+	+
Harbor porpoise (*Phocoena phocoena*)	PT	–	+
Killer whale (*Orcinus orca*)	–	+	+
Melon-headed whale (*Peponocephala electra*)	–	+	+
Northern bottlenose whale (*Hyperoodon ampullatus*)	–	–	+
Pantropical spotted dolphin (*Stenella attenuata*)	–	++	++
Pilot whale (*Globicephala* spp.)[c]	–	++	++
Pygmy killer whale (*Feresa attenuata*)	–	+	+
Pygmy sperm whale (*Kogia breviceps*)	–	+	+
Risso's dolphin (*Grampus griseus*)	–	++	++

Table 2-1. (Continued).

Common and Scientific Name	Status[a]	Historical Presence[b]	
		Mayport	Norfolk
Rough-toothed dolphin (*Steno bredanensis*)	--	+	+
Sowerby's beaked whale (*Mesoplodon bidens*)	--	--	+
Sperm whale (*Physeter macrocephalus*)	E	+	+
Spinner dolphin (*Stenella longirostris*)	--	++	++
Striped dolphin (*Stenella coeruleoalba*)	--	+	+
True's beaked whale (*Mesoplodon mirus*)	--	+	+
SEALS (Pinnipeds)			
Harbor seal (*Phoca vitulina*)	--	--	+

[a] Status: E = endangered species, PT = proposed for listing as a threatened species. The PT designation for the bottlenose dolphin applies only to the coastal population, which is not likely to occur at either offshore area. All non-listed (i.e., not listed as endangered or threatened) marine mammals are afforded protected status under the Marine Mammal Protection Act.

[b] Historical Presence: ++ = presence probable based on historical sightings data; + = presence possible based on historical sightings data, but a depth or latitudinal limit may exist; -- = presence not expected. Sources: Leatherwood et al., 1976; CETAP, 1982; Duffield et al., 1983; Payne et al., 1984; Lee, 1985a; Duffield, 1986; Kenney et al., 1986; Winn et al., 1986; Kenney and Winn, 1987; Kraus et al., 1988, 1993; Knowlton and Kraus, 1989; Manomet Bird Observatory, 1989; Hersh and Duffield, 1990; Kenney, 1990; Mayo and Marx, 1990; DOI, MMS, 1990; Kraus and Kenney, 1991; Mitchell, 1991; NMFS, 1991a,b; Payne and Heinemann, 1993; Schaeff et al., 1993; Blaylock and Hoggard, 1994.

[c] The two species of pilot whales in the western Atlantic, the long-finned pilot whale (*Globicephala melaena*) and short-finned pilot whale (*G. macrorhynchus*), are difficult to differentiate in the field and have been combined in this analysis.

and abundance (Blaylock et al., 1995). It is thought that migration south to the Caribbean occurs during fall. This species feeds largely on euphausiids and small fish such as herring, capelin, and sand lance. Calving and breeding occurs in the Caribbean from January to March. Gestation lasts 10 months and calves are suckled for about 11 months. Critical habitats have been identified in the western Gulf of Maine and the Great South Channel (Massachusetts). The minimum population estimate for the North Atlantic range of the humpback whale is 4,865 individuals (Blaylock et al., 1995).

Northern right whales (*Eubalaena glacialis*) range from Iceland to eastern Florida, with occasional sightings in the Gulf of Mexico. This is the rarest of the world's baleen whales, with a current North Atlantic population between 325 and 350 individuals (Kraus et al., 1993). Coastal waters of the southeastern U.S. (i.e., off Georgia and northeast Florida) are important wintering and calving grounds for northern right whales, while the waters around Cape Cod and Great South Channel are used for feeding, nursery, and mating during summer (Kraus et al., 1988; Schaeff et al., 1993). From June to September, most animals are found feeding north of Cape Cod. Right whale mating probably occurs during late summer; gestation lasts 12 to 16 months, and calves are suckled for about 1 year (Knowlton and Kraus, 1989). Southward migration occurs offshore from mid-October to early January, although right whales may arrive off the Florida coast as early as November and may stay into late March (Kraus et al., 1993). Migration northward along the coast of Florida takes place between early January and late March. Coastal waters off the Carolinas may represent a migratory corridor for this species (Winn et al., 1986; Kraus et al., 1993). It has been suggested that during the spring migration, right whales typically transit offshore North Carolina in shallow water immediately adjacent to the coast; fall migrations may occur further offshore in this region (Department of the Interior, Minerals Management Service, 1990). This species usually occurs shoreward of the 200-m (656-ft) contour line. Preferred water depths during recent surveys off the Florida coast range from 3 to 73 m (10 to 240 ft), with a mean of 12.6 m (41.3 ft) (Kraus et al., 1993).

Designated critical habitat for the northern right whale includes portions of Cape Cod Bay and Stellwagen Bank and the Great South Channel (off Massachusetts) and waters adjacent to the coasts of Georgia and northeast Florida [Federal Register 59(106):28793-28808]. The southernmost critical habitat encompasses "waters between 31°15'N (i.e., near the mouth of Altahama River, Georgia) and 30°15'N (i.e., near Jacksonville, Florida) from the shoreline out to 15 nautical miles offshore, and the waters between 30°15'N and 28°00'N (i.e., near Sebastian Inlet, Florida) from the shoreline out to 5 nautical miles."

Sei whales (*Balaenoptera borealis*) range from south of the Arctic to northeast Venezuela, including the Gulf of Mexico. This species is considered to be pelagic and widely distributed from below polar seas to the Caribbean. It is believed that the following three main stocks occur: (1) Newfoundland/Labrador; (2) Nova Scotia; and (3) Caribbean/Gulf of Mexico. The Nova Scotia stock migrates along the coast, with occurrence south of Cape Cod in winter and from Cape Cod north to the Arctic in summer. This species feeds on copepods, krill, and small schooling fish such as anchovies, sauries, and mackerel. Peak pairing is reported to be from November to February in temperate waters. Gestation lasts 1 year and calves are born in February in warmer waters. Calves are suckled for 6 months. Large numbers concentrate in feeding

grounds but usually travel in groups of 2 to 5 individuals. Existing data are insufficient for obtaining estimates of population size in the Atlantic (Blaylock et al., 1995).

Toothed Whales

Sperm whales (*Physeter macrocephalus*) range from the Davis Straits to Venezuela, including the Gulf of Mexico. This species is pelagic, occurring along the continental shelf edge and slope, continuing into mid-ocean areas; it is occasionally found on the shelf. Sperm whales generally feed on mesopelagic (open ocean environment between 150 and 1,000 m [492 and 3,281 ft] depth) squid along the 1,000-m (3,281-ft) contour. North-south migratory routes observed through middle Atlantic areas are always inhabited. Females, calves, and juveniles remain south of 40°N to 42°N latitude throughout the year while mature males range to higher latitudes (68°N) during summer. This species is most abundant during spring. Mating season is prolonged, extending from late winter through early summer. Calves are born once every 3 to 6 years. Calving occurs between May and September in the northern hemisphere. Large, old males are solitary, while females, calves, and juveniles form "breeding schools" with 4 to 150 individuals. Young males form segregated bachelor groups, or "schools", of up to 50 individuals. The sperm whales which occur along the eastern U.S. represent only a fraction of the total stock. The nature of linkages of this habitat with others is unknown. Their minimum population estimate is 226 individuals (Blaylock et al., 1995).

2.1.2 Nonlisted Marine Mammals

Nonlisted marine mammals that may occur in the area include both baleen whales and toothed whales. Two nonlisted baleen whale species may occur within the area: Bryde's whale (*Balaenoptera edeni*) and the minke whale (*Balaenoptera acutorostrata*). Both are in the Family Balaenopteridae (rorquals). In addition, 21 nonlisted toothed whale species may occur within the area, including representatives of four families (i.e., Ziphiidae, Kogidae, Stenidae, and Delphinidae).

Baleen Whales

Bryde's whales (*Balaenoptera edeni*) range from off the southeastern U.S. including the Gulf of Mexico to the southern Caribbean Sea and Brazil (Leatherwood and Reeves, 1983). This species is found primarily in tropical and subtropical waters, and seldom occurs above 40°N except in warm-water (above 20°C [68°F]) projections northward. Bryde's whales are not thought to undergo long migrations. Some northward movements during summer and southward movements during winter have been observed and suggest pursuit of prey. This species typically inhabits nearshore waters and feeds on schooling fish such as sardines, mackerel, anchovies, and herrings. Bryde's whales are relatively uncommon. Information from South African waters suggests they breed year round.

Minke whales (*Balaenoptera acutorostrata*) have a widespread distribution in polar, temperate, and tropical waters. There are four recognized minke whale populations in the North Atlantic. Minke whales off the U.S. eastern seaboard are considered part of the Canadian East Coast population which covers the area from the eastern half of the Davis Strait out to 45°W and south to the Gulf of Mexico (Blaylock et al., 1995).

Along the U.S. east coast, the minke whale is the third most common large whale in the region [Cetacean and Turtle Assessment Program (CETAP), 1982]. Blaylock et al. (1995) noted a strong seasonal component to minke whale distribution, with wide-spread and common occurrence of this species off the eastern coast of the U.S. in spring and summer. Minke whales are observed north of Cape Cod in summer, commonly in nearshore waters of the Gulf of Maine and Bay of Fundy. Migrations occur northward during spring and southward in fall. It is believed that this species spends winter offshore of south Florida and the Lesser Antilles. Mitchell (1991) suggested a possible winter distribution in the West Indies and the mid-ocean south and east of Bermuda. Lee (1985a) indicated that minke whales may winter off the North Carolina coast, but are absent during other seasons. Manomet Bird Observatory (1989) recorded rare sightings of this species in summer, autumn, and winter (i.e., 2 to 5 individuals/100 transects) on the shelf north of Cape Hatteras. Sightings typically occur nearshore or within the 200-m (656-ft) contour. Like most other baleen whales, minke whales typically occupy the shelf proper, rather than the shelf edge (Blaylock et al., 1995). Preferred prey include herring, cod, salmon, capelin, squid, and shrimp (Leatherwood et al., 1976). Pairing is normally observed during October to March, coincident with calving. Gestation is about 10 to 11 months; nursing lasts for less than 6 months. It is believed that this species is more solitary though large groups have been observed. The minimum population estimate of minke whales in the eastern U.S./Canadian population is unknown (Blaylock et al., 1995). Minke whale abundance data acquired by shipboard surveys conducted during 1991-92 estimated 2,053 individuals (Blaylock et al., 1995).

Toothed Whales and Dolphins

Family Ziphiidae. There are six species of beaked whales which occur in the Mayport and Norfolk areas (Leatherwood et al., 1976; Hansen and Blaylock, 1994), including the Northern bottlenose whale (*Hyperoodon ampullatus*), Blainville's beaked whale (*Mesoplodon densirostris*), Gervais' beaked whale (*M. europaeus*), True's beaked whale (*M. mirus*), Sowerby's beaked whale (*M. bidens*), and Cuvier's beaked whale (*Ziphius cavirostris*). The members of the genus *Mesoplodon* are difficult to identify to the species level at sea. Therefore, much of the available characterization for these species is to genus level only. Similarly, the elusive nature of *Mesoplodon* spp. has, to date, prevented the acquisition of sufficient data to determine specific population trends (Blaylock et al., 1995). Beaked whales are currently classified as a "strategic stock" by the NMFS (Blaylock et al., 1995).

Northern bottlenose whales (*Hyperoodon ampullatus*) are found only in temperate to arctic waters of the North Atlantic. They follow a relatively well-defined migratory pattern, and are found at low latitudes only during winter (Leatherwood and Reeves, 1983). They are deep divers and appear to feed primarily on squid and fish (Leatherwood and Reeves, 1983; Jefferson et al., 1993). They are characterized as extremely uncommon or rare in the northern Atlantic, and current data are insufficient to determine population size (Blaylock et al., 1995).

Blainville's beaked whales (*Mesoplodon densirostris*) range from Nova Scotia to Florida and the Bahamas, including waters of the Gulf of Mexico. This species is considered pelagic, inhabiting very deep waters. It is widely but sparsely distributed

throughout tropical and warm temperate waters up to 45°N latitude in the western Atlantic due to the presence of the Gulf Stream (Leatherwood et al., 1976). Data suggest that Blainville's beaked whales feed on squid and live in family groups of three to six individuals. Little is known about its life history.

Gervais' beaked whales (*Mesoplodon europaeus*) are considered pelagic, and strandings have been reported from the Middle Atlantic Bight to Florida into the Caribbean and the Gulf of Mexico (Blaylock et al., 1995). Data suggest that the preferred prey of this species is squid.

True's beaked whales (*Mesoplodon mirus*) are a temperate water species that has been reported from Cape Breton Island, Nova Scotia to the Bahamas (Leatherwood et al., 1976). It is suggested that these whales are pelagic due to their infrequent stranding record. It is believed that True's beaked whales feed on squid as well as a variety of fish. As with other *Mesoplodon* spp., little is known about their life history.

Sowerby's beaked whales (*Mesoplodon bidens*) are known only from temperate to subarctic waters of the North Atlantic, and data suggest that they are more common in European than American waters (Leatherwood and Reeves, 1983). As with other *Mesoplodon* spp., little is known of their life history (Blaylock et al., 1995).

Cuvier's beaked whales (*Ziphius cavirostris*) range from Massachusetts to the West Indies, including waters of the Gulf of Mexico. Stock structure in the northwestern Atlantic is unknown (Blaylock et al., 1995). As with other beaked whales, it is believed that this species inhabits pelagic waters and exhibits a wide distribution. Migration to higher latitudes during summer has been suggested. This species feeds primarily on squid and deep water fish, but is also known to eat crab and starfish. No marked breeding season is evident. It is believed that calving occurs year-round. Cuvier's beaked whales form family groups of about 15 individuals. Little is known about the life history of this species. Sightings from CETAP (1982) surveys indicate the presence of Cuvier's beaked whales over the shelf break throughout the middle Atlantic region, with highest sightings recorded for late spring and summer.

Family Kogidae. The pygmy sperm whale (*Kogia breviceps*) and the dwarf sperm whale (*Kogia simus*) appear to be distributed worldwide in temperate to tropical waters along the continental shelf edge and continental slope (Blaylock et al., 1995). As in the case of beaked whales, pygmy sperm whales and dwarf sperm whales are difficult to distinguish and are typically categorized as *Kogia* spp. There is no information on Atlantic stock differentiation and population size for these species (Blaylock et al., 1995). However, results cited by Hansen and Blaylock (1994) for a 1992 survey in the South Atlantic indicated a *Kogia* spp. population (i.e., *K. breviceps*, and dwarf sperm whales [*K. simus*]) of 420 individuals. Estimates of abundance were derived from 1992 winter observations using line-transect techniques between Cape Hatteras, North Carolina and Miami, Florida. *Kogia* are rarely seen alive at sea, but they are among the most frequently stranded small whales in some areas (Jefferson et al., 1993), including the southeastern U.S.

Family Stenidae. The family Stenidae includes the rough-toothed dolphin (*Steno bredanensis*). This species is distributed worldwide in tropical to warm temperate

waters (Blaylock et al., 1995). Within the western Atlantic they range from Virginia and North Carolina to northeastern South America, including eastern and northwestern Gulf of Mexico waters (Leatherwood and Reeves, 1983). This species is pelagic and usually found seaward of the continental slope edge. Little is known about its life history and no information exists on stock differentiation and population levels in the Atlantic (Blaylock et al., 1995).

Family Delphinidae. The family Delphinidae is taxonomically diverse and includes dolphins, killer whales, false killer whales, pygmy killer whales, Risso's dolphins (or grampus), short-finned pilot whales, and melon-headed whales.

Spinner dolphins (*Stenella longirostris*) range from North Carolina to southern Brazil, including Gulf of Mexico waters. Though presumably an offshore, deep-water species, they occur in both oceanic and coastal tropical waters (Blaylock et al., 1995). Two reproductive peaks in spring and fall have been suggested. Stock structure and population estimates of spinner dolphins in the western North Atlantic is unknown (Blaylock et al., 1995).

Atlantic spotted dolphins (*Stenella frontalis*) range from New Jersey to Venezuela, including waters of the Gulf of Mexico. This species is found in warm temperate and tropical waters. The Atlantic spotted dolphin inhabits the continental shelf and slope, though southern populations occasionally come into shallow coastal waters. Favored prey include herrings, anchovies, and carangid fish. Mating has been observed in July, with calves born offshore. Atlantic spotted dolphins often occur in groups of up to 50 individuals. Stock structure in the western North Atlantic is unknown. The minimum population estimate of 4,896 individuals was determined by the NMFS (in Blaylock et al., 1995).

Striped dolphins (*Stenella coeruleoalba*) range from Nova Scotia to the Lesser Antilles, including the Gulf of Mexico. These dolphins are distributed worldwide in temperate and tropical waters. This species is considered to be found along the continental slope from the Gulf of Mexico to Georges Bank. Migratory patterns are uncertain. There is no information on stock differentiation and population size in the Atlantic (Blaylock et al., 1995).

Pantropical spotted dolphins (*Stenella attenuata*) range from Massachusetts to the Lesser Antilles, including waters of the eastern Gulf of Mexico. They are distributed worldwide in subtropical and tropical oceans. They appear to prefer waters of the continental slope (Blaylock et al., 1995). It is believed that this species feeds on squid, fish, and shrimp. This species is often found in association with schools of tuna. Pantropical spotted dolphins occur in groups of 5 to 30 individuals. Little is known about their life history. There is no information available on stock differentiation and current population estimates for the Atlantic population (Blaylock et al., 1995).

Clymene dolphins (*Stenella clymene*) are widely distributed in subtropical and tropical waters of the Atlantic where they occur in the same geographic areas as *S. longirostris*. It is believed that this species lives over the deeper waters off the continental shelf (Blaylock et al., 1995). Little is known about its life history, and data on

stock differentiation and population estimates in the Atlantic are not available (Blaylock et al., 1995).

Common dolphins (*Delphinus delphis*) range from Newfoundland and Nova Scotia to northern South America. They are distributed in worldwide temperate, tropical, and subtropical offshore waters on the continental slope, shelf, and shelf edge (Blaylock et al., 1995). According to Kenney and Winn (1987), CETAP (1982) results indicated the temporal presence of saddleback dolphins off the northeast U.S. coast in fall and winter, a trend which is the reverse of that exhibited by *Stenella* spp. and most other cetacean taxa, indicative of possible resource partitioning. The species is less common south of Cape Hatteras (Blaylock et al., 1995). Kenney and Winn (1987) also noted the possible co-occurrence of common dolphins with Atlantic spotted dolphins (*Stenella frontalis*). Common dolphins feed on epipelagic and mesopelagic fish, squid, and demersal fish (Kenney and Winn, 1987). Breeding is seasonal. Gestation lasts 10 to 11 months, with calves born in spring and fall. The minimum population estimate of 3,321 individuals was determined by the NMFS (in Blaylock et al., 1995).

Fraser's dolphins (*Lagenodelphis hosei*) are distributed worldwide in tropical waters. This species appears to be largely oceanic, with preferred prey including shrimp, fish, and squid. Fraser's dolphins are found in groups of up to 500 individuals. Little is known about the life history of this species. There is no information on stock differentiation and population size in the Atlantic (Blaylock et al., 1995).

Atlantic white-sided dolphins (*Lagenorhynchus acutus*) are found in temperate and sub-polar waters of the North Atlantic, and appear to prefer deep waters of the outer continental shelf and slope. This species ranges from central West Greenland to Chesapeake Bay. Population estimates from aerial surveys between Cape Hatteras, North Carolina and Nova Scotia (Canada) from 1978 to 1982 (CETAP, 1982) was 28,600 individuals. Minimum population estimates based on 1991-92 shipboard survey abundance data was 12,540 individuals (Blaylock et al., 1995).

Bottlenose dolphins (*Tursiops truncatus*) in the western Atlantic range from Nova Scotia to Venezuela, as well as the waters of the Gulf of Mexico (Hansen and Blaylock, 1994). This species is distributed worldwide in temperate and tropical inshore waters. Middle Atlantic populations are represented by a hematologically and morphologically distinct offshore stock and coastal stock (Duffield et al., 1983; Duffield, 1986; Hersh and Duffield, 1990; Hansen and Blaylock, 1994). Aerial survey results reported by CETAP (1982) and Kenney (1990) indicated the offshore stock extends along the entire shelf break from Georges Bank to Cape Hatteras during spring and summer. During fall, this distribution compressed towards the south, with fewer sightings in winter. According to Kenney (1990), the offshore stock is concentrated along the shelf break, extending beyond the shelf edge in lower concentrations. Peak average estimated abundance for the offshore stock occurred during fall and was estimated to be 7,696 individuals (Hansen and Blaylock, 1994). No abundance estimates are available for the offshore stock south of Cape Hatteras (Blaylock et al., 1995). Recent research has indicated that there are a variety of stock structures possible within the coastal Atlantic bottlenose dolphin population both north and south of Cape Hatteras. Blaylock and Hoggard (1994), reporting results from the Southeast Cetacean Aerial Survey (SECAS) study (i.e., continental shelf waters; Cape Hatteras, North Carolina to mid-Florida; Gulf of Mexico waters), developed abundance estimates for the shallow,

warm water Atlantic bottlenose dolphin ecotype. The offshore distribution of coastal bottlenose dolphins south of Cape Hatteras has not been described. Blaylock and Hoggard (1994) noted, however, the possibility for coexistence of the coastal and offshore stocks inhabiting the edge of the outer continental shelf and slope waters south of Cape Hatteras. Bottlenose dolphins feed on shrimp and fish. Mating and calving occur from February to May in Florida waters. The calving interval is 2 to 3 years. They are found in groups of up to several hundred individuals with group sizes increasing with distance from shore. The coastal stock of the bottlenose dolphin population is currently considered a candidate for threatened species status.

Harbor porpoises (*Phocoena phocoena*) are found in cool temperate and subpolar waters of the Northern Hemisphere. They are typically found in shallow water, most often nearshore, although occasionally travel over deeper offshore waters (Jefferson et al., 1993). During summer, harbor porpoises are concentrated in Canada and the northern Gulf of Maine. During fall and spring, they are widely distributed from Maine to North Carolina (Blaylock et al., 1995). The minimum population estimate was 40,345 individuals (Blaylock et al., 1995). This species has recently been proposed for listing as a threatened species.

Killer whales (*Orcinus orca*) are characterized as uncommon or rare in waters of the western Atlantic. They are distributed from the Arctic pack ice to the Lesser Antilles, including waters of the Gulf of Mexico. Migration is thought to occur in association with changes in food abundance. Killer whales feed on squid, fish, sea turtles, seabirds, and other marine mammals. It is believed that mating occurs throughout the year, with gestation requiring about 1 year. Killer whales are found in groups ranging from a few to 25 to 30 individuals, where social structure and territoriality may be important. Stock definition and population estimates in the Atlantic are unknown (Blaylock et al., 1995).

False killer whales (*Pseudorca crassidens*) range from Maryland to Venezuela, including Gulf of Mexico waters. This species is distributed worldwide in tropical and temperate waters. False killer whales are generally considered to be oceanic but individuals have been observed in cool, nearshore waters. This species feeds on squid and fish. It is believed that mating occurs year round, with a gestation period of about 15 months. False killer whales are found in large groups composed of smaller family groups of four to six individuals. Stock definition and population estimates in the Atlantic are unknown (Blaylock et al., 1995).

Pygmy killer whales (*Feresa attenuata*) range from North Carolina to the Lesser Antilles, as well as Gulf of Mexico waters. This species is distributed worldwide in tropical and warm temperate waters. Preferred prey includes small fish. Nocturnal feeding has been noted for this species. It is believed that calving occurs in spring. This species is typically found in groups of 10 individuals. Little is known about its life history. Stock definition and population estimates in the Atlantic are unknown (Blaylock et al., 1995).

Risso's dolphins (*Grampus griseus*) range from eastern Newfoundland to the Lesser Antilles and Gulf of Mexico. This species is distributed worldwide in tropical to temperate waters. It is believed that Risso's dolphins undergo north-south, summer-winter migrations. Off the northeast U.S. coast, Risso's dolphins are distributed along the

shelf edge from Cape Hatteras northward to Georges Bank during spring, summer, and fall (CETAP, 1982; Payne et al., 1984). In winter, this species ranges further offshore (Blaylock et al., 1995). Typically, this species occupies the continental shelf edge year-round. This species feeds mainly on squid. Risso's dolphins are found in groups of 3 to 30, although groups of up to several hundred individuals have been reported. Total numbers of Risso's dolphins off the eastern U.S. coast are unknown. CETAP (1982) survey results indicated a population estimate of 4,980 individuals. Current data are insufficient to determine stock differentiation and population trends in the Atlantic. This species is considered a "strategic stock" under the MMPA (Blaylock et al., 1995).

Short-finned pilot whales (*Globicephala macrorhynchus*) occur in the western Atlantic from New Jersey to Venezuela, as well as in waters of the Gulf of Mexico. This species is found worldwide in warm temperate and tropical waters. Sightings of pilot whales typically occur seaward of the continental shelf edge and within waters of the Gulf Stream (Blaylock et al., 1995). Little is known about migration. Preferred prey items include squid and fish. It is believed that this species has an extended breeding and calving season in warm waters. Short-finned pilot whales have been observed chasing and feeding on schools of tuna. There is no information on stock differentiation for the Atlantic population. Estimated abundance of pilot whales between Miami, Florida and Cape Hatteras, North Carolina, derived from a 1992 shipboard survey, was 749 individuals (Blaylock et al., 1995).

Long-finned pilot whales (*Globicephala melas*) are distributed from Iceland to North Carolina. They are commonly found in both oceanic and certain coastal waters of the North Atlantic (Jefferson et al., 1993). The stock structure of the North Atlantic population is currently unknown (Blaylock et al., 1995).

Melon-headed whales (*Peponocephala electra*) are distributed worldwide in tropical to sub-tropical waters (Blaylock et al., 1995). Melon-headed whales are highly social, and are known to occur in pods of 100 to 500 animals. They are often seen swimming with dolphin species and are known to feed on squid and small fish. There is some evidence to indicate a calving peak in July and August, but this evidence is inconclusive (Jefferson et al., 1993). There is no information on stock differentiation and population estimates in the Atlantic (Blaylock et al., 1995).

Pinnipeds

Harbor seals (*Phoca vitulina*) are widely distributed from temperate to polar regions of the Northern Hemisphere. Along the eastern U.S. they are found from the Canadian Arctic to the mid-Atlantic (Jefferson et al., 1993). At sea, they are mainly found in coastal waters of the continental shelf and slope.

2.2 AERIAL SURVEY RESULTS

Between April and September 1995, six aerial surveys of the Mayport and Norfolk areas were conducted to estimate densities of marine mammals and sea turtles. The data were used to support development of the DEIS (Department of the Navy, 1996) and associated documents. The two survey areas lie along the 152 m (500 ft) depth contour within 185 km (100 nmi) of naval facilities at Mayport, Florida or Norfolk, Virginia.

Results of the aerial surveys are summarized below. Survey methods are outlined in Appendix A.

For the Norfolk area, sightings data (i.e., total number of individuals observed during April through September 1995 surveys) were used to develop mean density estimates for each species or species group. Because there would be no shock testing in April at Mayport, mean densities for Mayport were calculated for the May-September period (i.e., excluding April). Mean densities calculated from these aerial observations did not take into account submerged individuals or those that may have been on the surface but undetected. Therefore, adjusted densities were developed for each species seen during the surveys. The methods and assumptions employed to develop adjusted densities (i.e., to account for submerged and undetected individuals) are explained in Appendix B. Densities are presented as numbers of individuals per 100 km^2 (29.2 nmi^2).

2.2.1 Toothed Whales (Odontocetes)

Mayport Area

Based on historical data records, only one species of endangered toothed whale, the sperm whale (*Physeter macrocephalus*), could be expected to occur at the Mayport area. In addition, a review of historical sighting records indicates there are 21 nonlisted species of toothed whales and dolphins which may be found in this region (**Table 2-1**).

Results of the 1995 surveys indicated a total of 1,303 odontocetes observed off Mayport representing only nine species or species groups (**Table 2-2**). Only one endangered toothed whale species, the sperm whale (*Physeter macrocephalus*), was seen; a pair of individuals was observed during May 1995. Nonlisted marine mammals, however, were frequently observed during the entire survey period. Only one species of small whale, Risso's dolphin (*Grampus griseus*), was observed within the survey area. A total of 195 Risso's dolphins was observed over the entire survey period, primarily during the May survey. Dolphins were frequently observed within the survey area, with high variability in numbers of both species and individuals. A total of four identifiable species (838 individuals total) and three dolphin species groups (268 individuals total) was observed during the survey period. By far, the most common dolphins observed were pantropical spotted dolphins (*Stenella attenuata*), bottlenose dolphins (*Tursiops truncatus*), and Atlantic spotted dolphins (*Stenella frontalis*), with 387, 245, and 156 individuals observed, respectively. Another species included the spinner dolphin (*Stenella longirostris*) with 50 individuals observed.

Figure 2-1 shows the abundance of marine mammals along individual transects at the Mayport site. Numbers of marine mammals on a transect ranged from 0 to 80 individuals; within any given survey, most transects had zero. Marine mammal abundance and frequency of occurrence was greatest during April and lowest during September. Marine mammals were generally more abundant and widespread in the southern half of the site.

Table 2-2. Abundance and density estimates for toothed whales at the Mayport area based on 1995 aerial surveys. Observed abundance, observed mean density, and adjusted mean density figures reflect both five- and six-month survey periods (i.e., May-September, with April-September in parentheses).

Species	Observed Abundance[a] (No. of Individuals)	Observed Mean Density[b] (Individuals/ 100 km^2)	Proportion of Population Detected[c]	Adjusted Mean Density[d] (Individuals/ 100 km^2)
Atlantic spotted dolphin (*Stenella frontalis*)	77 (156)	0.52 (0.88)	0.18	2.90 (4.90)
Bottlenose dolphin (*Tursiops truncatus*)	78 (245)	0.53 (1.39)	0.18	2.94 (7.70)
Bottlenose/Atlantic spotted dolphin (*Tursiops truncatus/ Stenella frontalis*)	26 (26)	0.18 (0.15)	0.18	0.98 (0.82)
Clymene/spinner/striped dolphin (*S. clymene/longirostris/ coeruleoalba*)	19 (44)	0.13 (0.25)	0.18	0.72 (1.38)
Pantropical spotted dolphin (*Stenella attenuata*)	229 (387)	1.55 (2.19)	0.18	8.63 (12.15)
Risso's dolphin (*Grampus griseus*)	175 (195)	1.19 (1.10)	0.18	6.60 (6.12)
Sperm whale (E) (*Physeter macrocephalus*)	2 (2)	0.01 (0.01)	0.09	0.15 (0.13)
Spinner dolphin (*Stenella longirostris*)	50 (50)	0.34 (0.28)	0.18	1.88 (1.57)
Unidentified dolphin	188 (198)	1.28 (1.12)	0.18	7.09 (6.22)
TOTAL TOOTHED WHALES	844 (1,303)	5.73 (7.37)	NA	31.89 (40.99)
TOTAL LISTED TOOTHED WHALES	2	0.01 (0.01)	0.09	0.15 (0.13)

(E) = endangered species. NA = not applicable.

a - Observed abundance = total individuals observed during five 1995 aerial surveys; parenthetic entries indicate total individuals observed during six 1995 aerial surveys;

b - Observed mean density = mean number of individuals/100 km^2, based on total number of individuals observed ÷ area viewed per survey (2,948 km^2) ÷ 5 (number of surveys) × 100 (100 km^2); parenthetic entries indicate mean density estimates based on six aerial surveys; densities shown are rounded to two decimal places, but calculations were done using original, unrounded data; some values may differ slightly from those one could calculate using the tabulated numbers;

c - Proportion of population believed to be detected by the aerial surveys, taking into account submerged individuals and those undetected on the surface (see Appendix B);

d - Adjusted mean density = observed mean density ÷ proportion detected (see Appendix B); parenthetic entries indicate adjusted mean density estimates based on six aerial surveys; densities shown are rounded to two decimal places, but calculations were done using original, unrounded data; some values may differ slightly from those one could calculate using the tabulated numbers; adjusted mean densities take into account estimated numbers of submerged individuals and those that may have been undetected on the surface, as described in Appendix B.

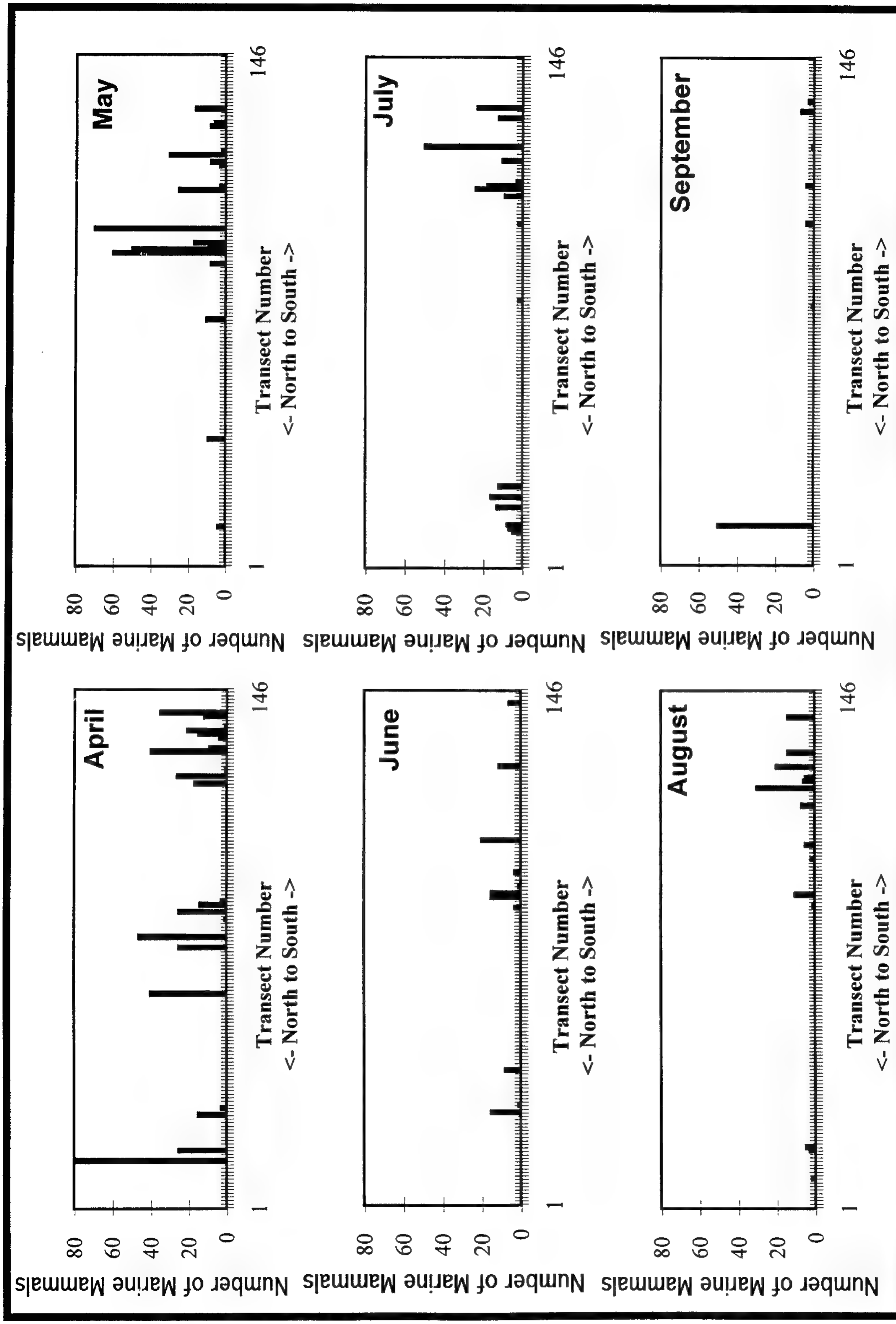


Figure 2-1. Marine mammal abundance along individual transects at the Mayport area during 1995 aerial surveys (Data from: Department of the Navy, 1995a).

Norfolk Area

Only one species of endangered toothed whale, the sperm whale (*Physeter macrocephalus*), would be expected to occur within the Norfolk area based on historical records. There are an additional 25 nonlisted species of toothed whales and dolphins which could be found at the Norfolk area. Twenty of these 25 species are the same as those which may be found within the Mayport area, as previously described (see **Table 2-1**). The five additional species historically occurring on the shelf edge off Virginia and North Carolina include the northern bottlenose whale (*Hyperoodon ampullatus*), melon-headed whale (*Peponocephala electra*), Sowerby's beaked whale (*Mesoplodon bidens*), long-finned pilot whale (*Globicephala melaena*), and Atlantic white-sided dolphin (*Lagenorhynchus acutus*). One species of seal may also be found within the Norfolk area, the harbor seal (*Phoca vitulina*).

Results of the 1995 surveys indicated a total of 4,370 odontocetes observed off Norfolk, representing 14 species or species groups (**Table 2-3**). The only endangered toothed whale species expected to be seen in the Norfolk area, the sperm whale (*Physeter macrocephalus*), was observed on only one occasion during 1995 aerial surveys. A total of four separate individuals was observed during April 1995. In contrast, nonlisted toothed whales were frequently observed. Large numbers of small whales, including pilot whales (*Globicephala* spp.) and Risso's dolphin (*Grampus griseus*) were commonly observed during most surveys. A total of 1,376 pilot whales was observed over the entire survey period, especially within the southern third of the area; a total of 119 Risso's dolphins was also noted. Only one species (and two individuals) of beaked whale, Cuvier's beaked whale (*Ziphius cavirostris*), was observed. Dolphins were frequently observed within the Norfolk survey area, with survey data exhibiting high variability in both numbers of species and individuals. A total of six identifiable dolphin species represented by 2,169 individuals was observed during the survey period; in addition, another 695 individuals representing three species groups were observed, for a total of 2,864 dolphins. By far, the most common dolphins observed were Atlantic spotted dolphins (*Stenella frontalis*) and bottlenose dolphins (*Tursiops truncatus*), with 824 and 514 individuals observed, respectively. Other species included pantropical spotted dolphins (*Stenella attenuata*, 435 individuals), common dolphins (*Delphinus delphis*, 310 individuals), and the spinner dolphin (*Stenella longirostris*, 22 individuals).

Figure 2-2 shows the abundance of marine mammals along individual transects at the Norfolk site. Numbers of marine mammals on a transect ranged from 0 to 250 individuals. During May through August surveys, about half of the transects had one or more marine mammal present, but during April and September, most transects had none. Marine mammals were generally more abundant in the southern half of the site.

2.2.2 Baleen Whales (Mysticetes)

Mayport Area

Based on historical data records, five species of endangered baleen whales could be expected to occur at the Mayport area, including blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*),

Table 2-3. Abundance and density estimates for toothed whales at the Norfolk area based on 1995 aerial surveys. Observed abundance, observed mean density, and adjusted mean density figures reflect a six-month survey period (i.e., April-September).

Species	Observed Abundance[a] (No. of Individuals)	Observed Mean Density[b] (Individuals/ 100 km^2)	Proportion of Population Detected[c]	Adjusted Mean Density[d] (Individuals/ 100 km^2)
Atlantic spotted dolphin (*Stenella frontalis*)	824	9.34	0.18	51.90
Bottlenose dolphin (*Tursiops truncatus*)	514	5.83	0.18	32.38
Bottlenose/Atlantic spotted dolphin (*Tursiops truncatus/Stenella frontalis*)	64	0.73	0.18	4.03
Clymene/spinner/striped dolphin (*S. clymene/longirostris/ coeruleoalba*)	245	2.78	0.18	15.43
Common dolphin (*Delphinus delphis*)	310	3.51	0.18	19.53
Cuvier's beaked whale (*Ziphius cavirostris*)	2	0.02	0.09	0.25
Pantropical spotted dolphin (*Stenella attenuata*)	435	4.93	0.18	27.40
Pilot whale (*Globicephala* spp.)[e]	1,376	15.60	0.18	86.67
Risso's dolphin (*Grampus griseus*)	119	1.35	0.18	7.50
Sperm whale (E) (*Physeter macrocephalus*)	4	0.05	0.09	0.50
Spinner dolphin (*Stenella longirostris*)	62	0.70	0.18	3.91
Striped dolphin (*Stenella coeruleoalba*)	24	0.27	0.18	1.51
Unidentified dolphin	386	4.38	0.18	24.31
Unidentified small whale	5	0.06	0.18	0.32
TOTAL TOOTHED WHALES	4,370	50.32	NA	280.05
TOTAL LISTED TOOTHED WHALES	4	0.05	0.09	0.50

(E) = endangered species. NA = not applicable.

a - Observed abundance = total individuals observed during six 1995 aerial surveys;

b - Observed density = mean number of individuals/100 km^2, based on total number of individuals observed ÷ area surveyed per survey (1,470 km^2) ÷ 6 (number of surveys) × 100 (100 km^2); densities shown are rounded to two decimal places, but calculations were done using original, unrounded data; some values may differ slightly from those one could calculate using the tabulated numbers;

c - Proportion of population believed to be detected by the aerial surveys, taking into account submerged individuals and those undetected on the surface (see Appendix B);

d - Adjusted mean density = observed mean density ÷ proportion detected (see Appendix B); parenthetic entries indicate adjusted mean density estimates based on six aerial surveys; densities shown are rounded to two decimal places, but calculations were done using original, unrounded data; some values may differ slightly from those one could calculate using the tabulated numbers; adjusted mean densities take into account estimated numbers of submerged individuals and those that may have been undetected on the surface, as described in Appendix B;

e - Both the long-finned pilot whale (*Globicephala melaena*) and the short-finned pilot whale (*G. macrorhynchus*) may occur within the Norfolk survey area (Blaylock et al., 1995). The two species are very difficult to differentiate in the field and have been combined in this analysis.

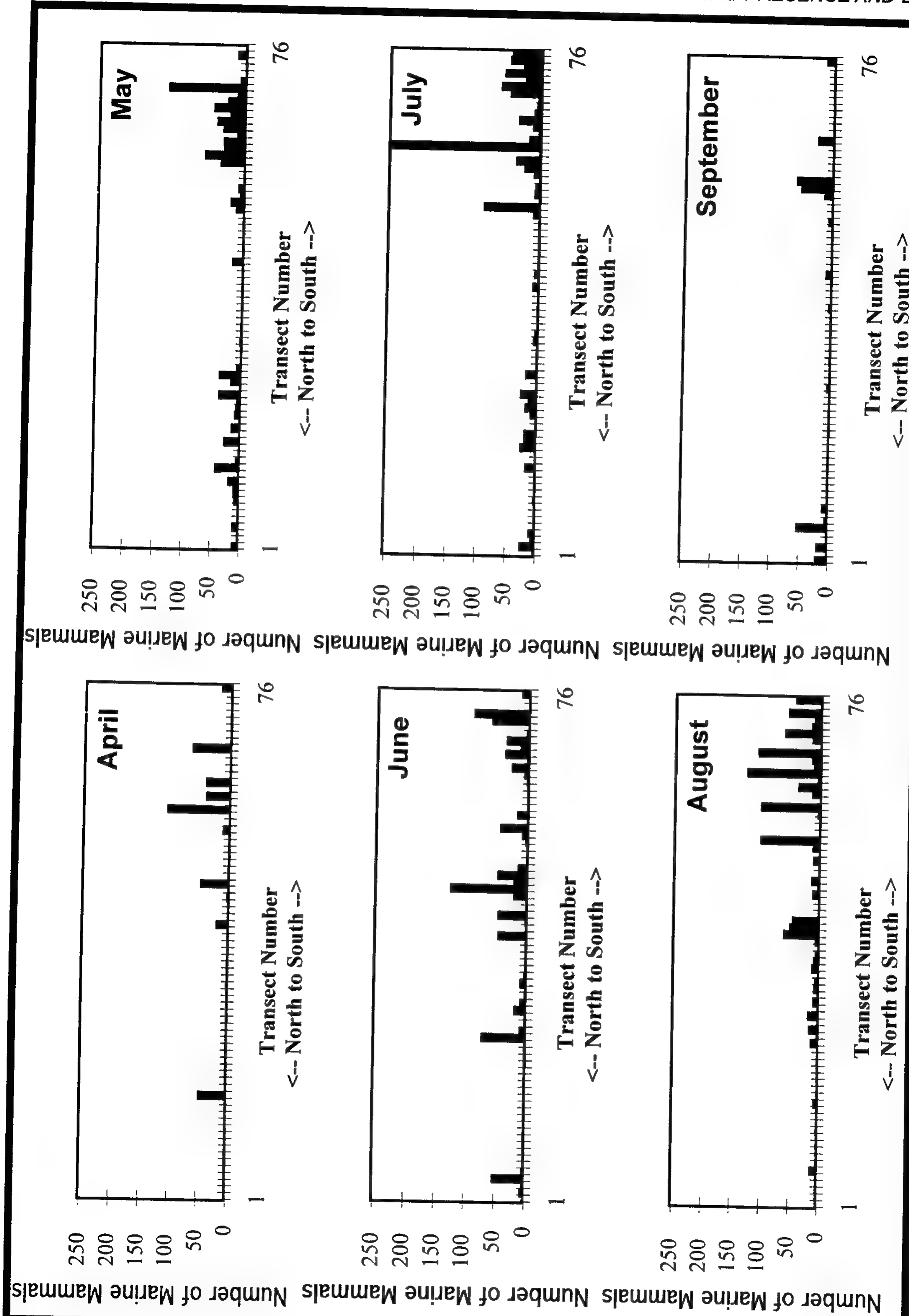


Figure 2-2. Marine mammal abundance along individual transects at the Norfolk area during 1995 aerial surveys (Data from: Department of the Navy, 1995a).

humpback whale (*Megaptera novaeangliae*), and northern right whale (*Eubalaena glacialis*). In addition, a review of historical sighting records indicates there are two nonlisted baleen species that may be found within the Mayport area: minke whale (*Balaenoptera acutorostrata*) and Bryde's whale (*Balaenoptera edeni*). However, no baleen whales were seen during the 1995 aerial surveys at the Mayport area.

Norfolk Area

Five species of endangered baleen whales could be expected to occur within the Norfolk area based on historical records, including blue (*Balaenoptera musculus*), fin (*B. physalus*), humpback (*Megaptera novaeangliae*), northern right (*Eubalaena glacialis*), and sei whales (*Balaenoptera borealis*). In addition, non-endangered minke (*B. acutorostrata*) and Bryde's whales (*B. edeni*), have also been historically recorded in this region.

Results of the 1995 surveys indicated a total of 68 mysticetes observed off Norfolk, representing seven species or species groups (**Table 2-4**). Four of the five endangered baleen whale species were observed during the surveys (i.e., blue whales not observed). Fin whales were the most common large whale encountered, with a total of 46 individuals observed during the survey period. Humpback, minke, and sei whales were observed only once or twice. The numbers of large whales observed decreased to zero during surveys after July, and it is presumed that these animals migrated to more northern waters.

2.2.3 Summary

Mayport Area

Including the numbers of unidentified individuals, the total number of marine mammals observed within the Mayport survey area was 1,303 individuals comprising one endangered toothed whale species, one species of nonlisted small toothed whale, and four species of nonlisted dolphins, plus three separate toothed species groups; no baleen whales were observed at the Mayport area during 1995 aerial surveys.

Many of the species with historical distributional records indicating a likelihood to occur within the Mayport area were not observed during the 1995 aerial surveys. Species such as dwarf and pygmy sperm whales (*Kogia* spp.) and pilot whales (*Globicephala* spp.) were not seen, although they occur frequently in stranding reports from the southeastern U.S. Some of these absences can be explained by seasonality (i.e., many species tend to inhabit northern feeding grounds during spring, summer, and early fall). Other factors possibly explaining species absence include low abundance, depth and/or habitat preferences outside of the area, year-to-year variability, and behavioral traits such as aircraft avoidance and short surface times in deep diving species.

Table 2-4. Abundance and density estimates for baleen whales at the Norfolk area based on 1995 aerial surveys. Observed abundance, observed density, and adjusted density figures reflect a six-month survey period (i.e., April-September).

Species	Observed Abundance[a] (No. of Individuals)	Observed Mean Density[b] (Individuals/ 100 km^2)	Proportion of Population Detected[c]	Adjusted Mean Density[d] (Individuals/ 100 km^2)
Balaenoptera spp.	12	0.14	0.18	0.76
Fin whale (E) (*Balaenoptera physalus*)	46	0.52	0.18	2.90
Humpback whale (E) (*Megaptera novaeangliae*)	1	0.01	0.18	0.06
Minke whale (*Balaenoptera acutorostrata*)	2	0.02	0.09	0.25
Sei whale (E) (*Balaenoptera borealis*)	2	0.02	0.18	0.13
Sei (E)/Bryde's whale (*Balaenoptera borealis/edeni*)	1	0.01	0.18	0.06
Unidentified large whale[e]	4	0.05	0.18	0.25
TOTAL BALEEN WHALES	68	0.75	NA	4.41
TOTAL LISTED BALEEN WHALES	49-66[f]	0.56-0.73[f]	NA	3.09-4.16[f]

(E) = endangered species. NA = not applicable.

a - Observed abundance = total individuals observed during six 1995 aerial surveys.

b - Observed mean density = mean number of individuals/100 km^2, based on total number of individuals observed ÷ area surveyed per survey (1,470 km^2) ÷ 6 (number of surveys) × 100 (100 km^2); densities shown are rounded to two decimal places, but calculations were done using original, unrounded data; some values may differ slightly from those one could calculate using the tabulated numbers;

c - Proportion of population believed to be detected by the aerial surveys, taking into account submerged individuals and those undetected on the surface (see Appendix B);

d - Adjusted mean density = observed mean density ÷ proportion detected (see Appendix B).

e - It has been assumed that the four unidentified large whales noted during May and June 1995 surveys were baleen whales, given that no large toothed whales were observed during either of these two surveys at the Norfolk site.

f - Low count of 49 based on the complete identification of fin, humpback, and sei whales only, all of which are listed as endangered; high count of 66 based on the 49 complete identifications previously noted, plus those individuals partially identified as Sei/Bryde's (1 individual), *Balaenoptera* spp. (12 individuals), and unidentified large whales (4 individuals), assuming that all partial identifications are of endangered (listed) species; observed mean densities computed for minimum and maximum abundances.

Norfolk Area

Including the numbers of unidentified individuals, the total number of marine mammals within the Norfolk survey area was 4,438 individuals comprising four species of listed baleen whales, one species of listed toothed whale, two species of nonlisted small or medium toothed whales, one species of nonlisted beaked whale, and six species of nonlisted dolphins; in addition, three additional dolphin species groups and one toothed whale group contributed abundance figures for the Norfolk area.

As was the case at the Mayport area, many of the species with historical distributional records indicating a likelihood to occur within the Norfolk area were not observed during the 1995 aerial surveys. Species such as dwarf and pygmy sperm whales (*Kogia* spp.) were not seen, although they occur frequently in stranding reports from the southeastern U.S. This may be attributed to a number of factors including seasonality, low abundance, depth and/or habitat preferences outside of the area, year-to-year variability, and behavioral traits such as aircraft avoidance and short surface times in deep diving species.

3.0 POTENTIAL IMPACTS ON MARINE MAMMALS

This section discusses three categories of incidental take of marine mammals:

(1) lethal "incidental take," i.e., death or mortal injury;

(2) injurious "incidental take," i.e., non-lethal internal organ or auditory system damage such as eardrum rupture or slight lung injury; and

(3) "harassment," i.e., disruption of behavioral patterns such as migration, breathing, nursing, breeding, feeding, or sheltering.

In addition, potential indirect effects on marine mammals through habitat alteration are discussed. Given that there is no potential for a reduction in the availability of species or species stocks used for subsistence purposes, the issue of incidental take relative to subsistence species is not addressed further.

The actual numbers of marine mammals that may be killed, injured, or harassed as a result of SEAWOLF shock testing cannot be known in advance. However, previous experience during the shock trial of the USS JOHN PAUL JONES, which involved detonation of two 4,536 kg (10,000 lb) charges, showed there were no marine mammal deaths or injuries (Naval Air Warfare Center, 1994) despite marine mammal densities that were about 3 times higher than at the Norfolk area and about 25 times higher than at the Mayport area (Department of the Navy, 1993). Similar mitigation methods are proposed for the SEAWOLF shock testing (see Section 4.0). In addition, based on the patchy distribution of marine mammals at the Mayport and Norfolk areas as shown in Figures 2-1 and 2-2, the Navy expects to be able to select a specific test site with few, if any, marine mammals present.

Estimates of incidental take outlined in the following sections are based on conservative assumptions. For example, maximum ranges for the onset of slight lung injury are based on slant ranges, which overestimate horizontal ranges. Also, ranges for eardrum rupture are in the category where eardrum rupture is considered "unlikely." Ranges for harassment are based on an "acoustic discomfort" criterion which is an overestimate of harassment because it would be a momentary disturbance that would not be expected to disrupt behavioral patterns such as migration, breathing, nursing, breeding, feeding, or sheltering. In addition, because the five detonations would occur at about one-week intervals, it is very unlikely that any individual animal would experience this momentary acoustic discomfort more than once.

3.1 MITIGATION AND SAFETY RANGE

The proposed action includes mitigation that would minimize risk to marine mammals (see Section 4.0). The Navy would (1) select an operationally suitable test site which poses the least risk to the marine environment; (2) effectively monitor the site prior to each detonation to ensure that it is free of marine mammals, turtles, large schools of fish, and flocks of seabirds; and (3) determine the effectiveness of the mitigation efforts by using a Marine Animal Recovery Team (MART) and aerial observers to survey the site

for injured or dead animals after each detonation. If post-detonation monitoring showed that marine mammals or turtles were killed or injured as a result of a detonation, testing would be halted until procedures for subsequent detonations could be reviewed and changed as necessary.

The concept of a safety range is integral to the mitigation plan. The safety range radius of 3.79 km (2.05 nmi) was calculated using information on eardrum rupture, which is the most conservative measure of non-lethal injury discussed in Appendix C. The maximum predicted horizontal distance for a 10% probability of eardrum rupture for a marine mammal is 3.79 km (2.05 nmi). A buffer zone of 1.8 km (0.95 nmi) was added to ensure that no marine mammal could enter the safety range while monitoring aircraft were completing their pre-detonation surveys. The safety range radius is more than twice the maximum range for lethality.

3.2 DEFINITION OF TAKE CATEGORIES AND RANGES

3.2.1 Lethal Incidental Take

Marine mammals can be killed or injured by underwater explosions due to the response of air cavities, such as the lungs and bubbles in the intestines, to the shock wave (Yelverton et al., 1973; Hill, 1978; Goertner, 1982). Effects are likely to be most severe in near surface waters above the detonation point where the reflected shock wave creates a region of negative pressure or "bulk cavitation." This is a region of near total physical trauma within which no animals would be expected to survive. Based on calculations in Appendix C, the maximum horizontal extent of the cavitation region is estimated at 494 m (1,620 ft) for the proposed detonations. This region would extend from the surface to a maximum depth of about 24 m (80 ft).

A second measure of possible mortality (and the one which is used here) is the maximum range for the onset of extensive lung hemorrhage. Extensive lung hemorrhage is considered debilitating and potentially fatal; suffocation caused by lung hemorrhage is likely to be the major cause of marine mammal death from underwater shock waves, based on experiments with terrestrial mammals (Hill, 1978). Calculations in Appendix C used the Goertner (1982) model to determine lung injury contours for the proposed detonations. For lung hemorrhage, Goertner's model considers lung volume as a function of animal weight and depth and considers shockwave duration and impulse tolerance as a function of animal weight and depth. The maximum range predicted for a small marine mammal (which would have the greatest range) is 1,524 m (5,000 ft) from the detonation point (**Figure 3-1**). This value is more conservative than the estimated lethal range of 70 to 800 m (230 to 2,625 ft) calculated by Ketten (1995) for the same size charge. *For purposes of impact analysis, it was assumed that 100% of the marine mammals within 1,524 m (5,000 ft) of the detonation point would be killed, even though the probability of mortality from extensive lung hemorrhage is estimated to be only 1% at the outer edge of this range.*

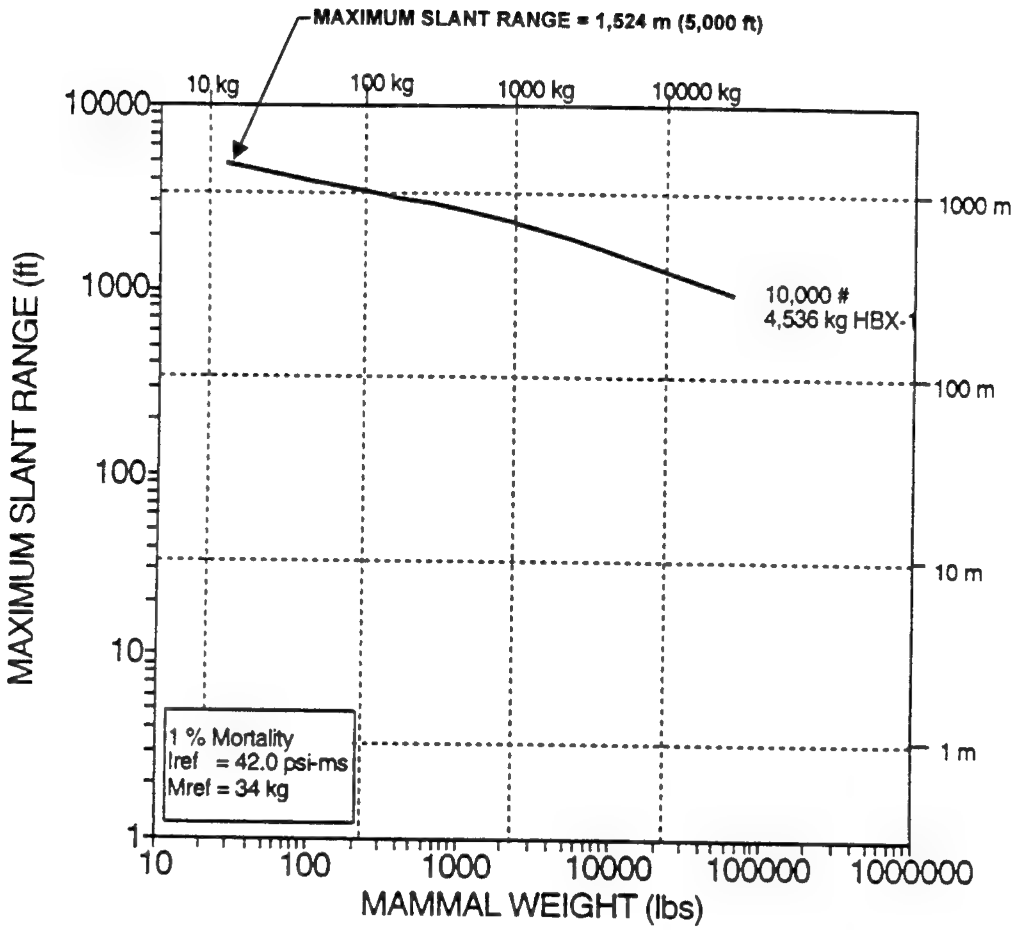


Figure 3-1. Maximum calculated ranges for 1% mortality (onset of extensive lung hemorrhage) as a function of mammal weight for a 4,536-kg (10,000-lb) charge (From: Appendix C).

3.2.2 Injurious Incidental Take

Two measures of non-lethal injury are also discussed in Appendix C: slight lung hemorrhage and eardrum rupture. These are injuries from which animals would be expected to recover on their own. The maximum range for slight lung hemorrhage is 1,850 m (6,069 ft). The maximum range for 10% probability of eardrum rupture varies from 2,408 m (7,900 ft) to 3,792 m (12,440 ft) depending on mammal depth in the water column. The latter value is for a mammal at the bottom (**Figure 3-2**). The 10% eardrum rupture range at the bottom was used as the maximum range for non-lethal injury. *For purposes of impact analysis, it was assumed that 100% of marine mammals between 1,524 m (5,000 ft) and 3,792 m (12,440 ft) from the detonation point would be injured, even though the probability of eardrum rupture at the outer edge of this range is only 10% (and less in near-surface waters).*

Eardrum damage criteria were established based on the results of small charge tests reported by both Yelverton et al. (1973) and Richmond et al. (1973). Tests conducted with dogs and sheep were considered in development of a conservative eardrum damage model. The test conditions and results from Richmond et al. (1973) are provided in Appendix C.

It is recognized that some percentage of the animals with eardrum rupture or slight lung hemorrhage could eventually die from their injuries. However, this is taken into account by the mortality criterion discussed above (onset of extensive lung hemorrhage), which deliberately overestimates mortality by assuming 100% of animals within a radius of 1,524 m (5,000 ft) would be killed. At this radius, the probability of eardrum rupture is 50% or less in the upper water column and 50% to 95% in deeper water (see Figure 11 in Appendix C); i.e., all animals within this radius are assumed to be killed even though some animals might not even have eardrum rupture.

3.2.3 Harassment

Harassment, as defined in the 1994 amendments to the Marine Mammal Protection Act of 1972, is "any act of pursuit, torment, or annoyance which (i) has the potential to injure a marine mammal or marine mammal stock in the wild;" (Level A harassment) or "(ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering" (Level B harassment). Level A harassment means injury, which has been discussed above. The NMFS has not defined a threshold for Level B harassment, but has cited temporary threshold shift (TTS) as an example (60 Federal Register at 28383, 31 May 1995). As explained below, there are currently insufficient data to develop a TTS criterion for marine mammals. Therefore, a criterion for "acoustic discomfort" has been used in this impact analysis. The number of marine mammals potentially experiencing acoustic discomfort is an overestimate of Level B harassment. Acoustic discomfort would be a momentary disturbance that would not cause TTS and would not be expected to cause disruption of behavioral patterns such as migration, breathing, nursing, breeding, feeding, or sheltering. In addition, because the five detonations would occur at about one-week intervals, it is very unlikely that any individual animal would experience this momentary discomfort more than once.

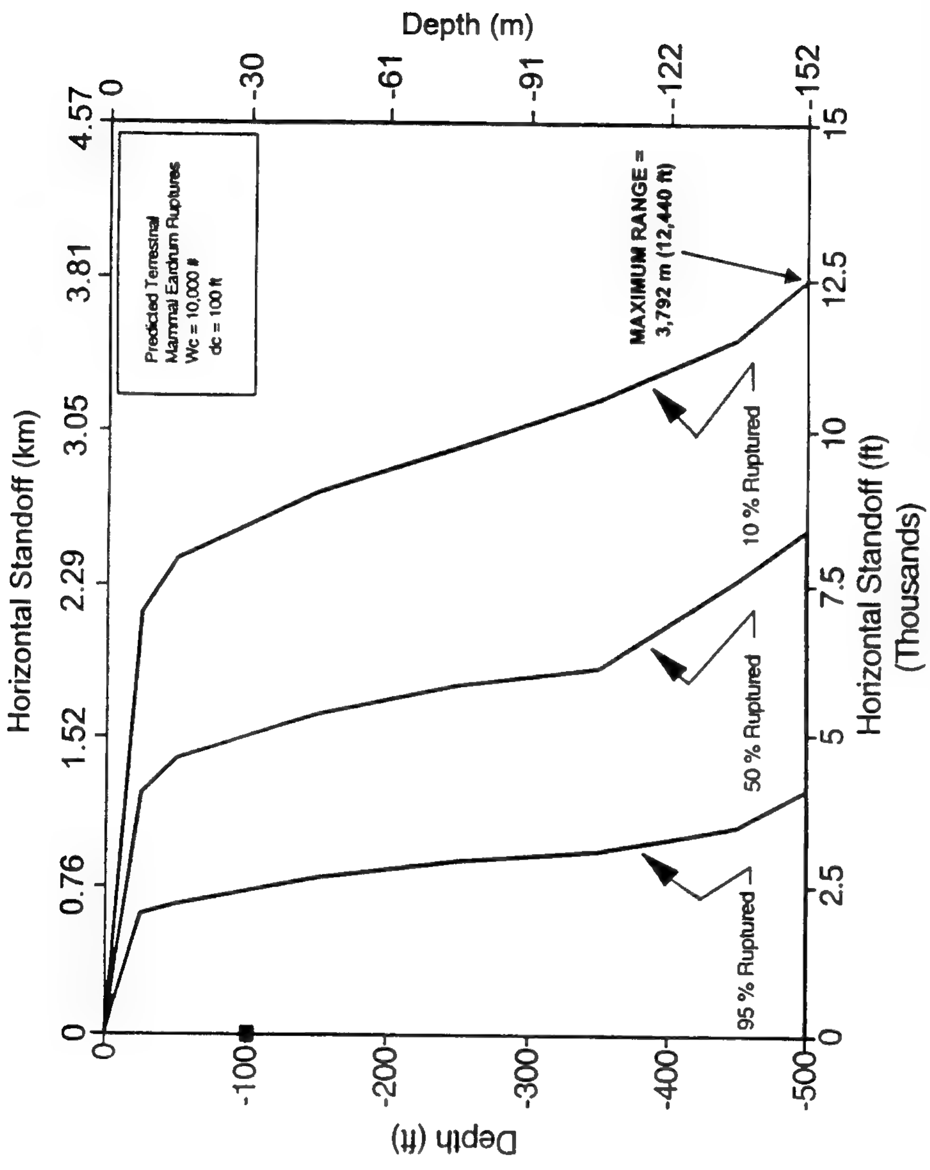


Figure 3-2. Eardrum rupture injury contours for a 4,536-kg (10,000-lb) charge (From: Appendix C).

An underwater explosion produces pressure pulses that have the potential for damaging the hearing of marine mammals (Ketten, 1995). Depending on an animal's distance from the detonation point, it could experience a temporary or permanent shift in the threshold of hearing (the quietest sound that the animal can hear), which could affect the animal's ability to hear calls, echolocation sounds, and other ambient sounds. Animals close to the detonation point could experience permanent threshold shift (PTS), which is permanent hearing loss. Animals at greater distances could experience temporary threshold shift (TTS). At still greater distances, animals could experience acoustic discomfort, which would be a momentary disturbance with no effect on hearing thresholds.

According to Richardson et al. (1995), the distances at which marine mammal auditory systems might be at risk for PTS from a single explosive pulse can be estimated based on extrapolations from human damage risk criteria. Based on the data presented by Richardson et al. (1995; p. 376), PTS might be expected to occur within distances of about 3.1 km (1.7 nmi) from the detonation point for a 4,536 kg (10,000 lb) charge. Ketten (1995) hypothesized a smaller PTS zone extending about 0.9 km (0.5 nmi) from the detonation point, within which >50% of animals would have some permanent hearing loss; and a PTS/TTS transitional zone extending from about 0.9 to 5 km (0.5 to 2.7 nmi) from the detonation point, within which most animals would have some temporary hearing loss but some permanent auditory damage would also be found. Based on these calculations and the fact that shock wave intensity decays exponentially with distance, it is reasonable to assume that PTS is unlikely to occur beyond the eardrum rupture range defined previously (3.79 km or 2.05 nmi). Therefore, PTS is not discussed further.

3.2.3.1 Acoustic Discomfort

To define the range (distance) of possible effects on marine mammal hearing, an interim criterion for acoustic discomfort was developed based on sound levels that would not cause TTS (Appendix D). The most meaningful criterion would be one based on measurements of TTS resulting from exposure of marine mammals to underwater noise. Although hearing thresholds for odontocetes and pinnipeds exposed to pure tones have been measured, there are no available TTS data for any marine mammals (Richardson et al., 1995). Therefore, other methods were used to develop a criterion for acoustic discomfort. Data obtained from humans immersed in water and exposed to brief pure tones were used, assisted by human in-air data, to construct an underwater hearing-safety limit for marine mammals. Evidence that indicates how safe this limit is has been provided in Appendix D. The acoustic discomfort criterion was then applied to define an acoustic discomfort range for the proposed detonations. Site-specific hydrographic data from the Mayport and Norfolk areas were used to calculate the acoustic discomfort range (Appendix D).

Based on the analysis in Appendix D, the maximum range for acoustic discomfort at the Mayport and Norfolk areas is 11.11 km (6 nmi). Expected numbers of marine mammals within this radius were calculated using adjusted mean densities from Section 2.2. Because only individuals outside the 3.79 km (2.05 nmi) safety range would be affected, the "with mitigation" and "without mitigation" numbers would be the same.

It is considered impractical to attempt to mitigate for possible acoustic discomfort, which is a momentary disturbance. Increasing the safety range from 3.79 km

(2.05 nmi) to 11.11 km (6 nmi) would increase the area by more than 850%, thus reducing the effectiveness of mitigation for mortality and injury.

3.2.3.2 Behavioral Responses

The acoustic signals emanating from the detonation would be brief, with most energy concentrated in the frequency ranges <500 Hz. Lehto (1992) indicates that the highest sound levels for a 4,536 kg (10,000 lb) detonation are found at very low frequencies, below 10 Hz. Further, the acoustic energy emanating from an underwater detonation is restricted to a few (i.e., <12 total) short pulses. Baleen whales are the marine mammals most likely to hear the brief acoustic signal because their hearing is best at low frequencies. The frequencies of best hearing for odontocetes tend to be in the 30 to 40 kHz range, where acoustic attenuation of the signal would be extremely high.

Research on behavioral reactions of marine mammals to impulsive noise has been summarized by Richardson et al. (1995). Although some controlled experiments have been conducted, most of the available information is anecdotal, with no data on the sound levels at the source and the receiver. Behavioral responses to sounds produced by underwater explosions and airgun arrays can include avoidance, altered patterns of surfacing and respiration, and interruptions in calling. Richardson et al. (1995) concluded that "some baleen whales show no strong behavioral reaction to noise pulses from distant explosions. They also show considerable tolerance of similar noise pulses from nonexplosive seismic exploration. However, strong seismic pulses elicit active avoidance, suggesting that explosives may sometimes do so as well."

There is not as much information available on the behavioral responses of toothed whales and dolphins (Richardson et al., 1995). Avoidance and/or interruptions in calling have been documented in sperm whales at great distances from airgun arrays (Bowles et al., 1994; Mate et al., 1994). Small explosive charges have often been used, with mixed success, to influence movement of dolphins (e.g., "seal bombs" used during purse-seining for yellowfin tuna).

It is reasonable to conclude that sounds produced by each detonation during SEAWOLF shock testing could startle marine mammals or result in avoidance or other subtle behavioral changes at distances beyond the acoustic discomfort range discussed above. However, animals outside this range would not experience any hearing damage or even brief acoustic discomfort. In addition, each detonation would be a single momentary event, and because the five detonations would occur at about one-week intervals, it is very unlikely that any individual animal would hear more than one detonation. Minor, momentary behavioral responses resulting from a marine mammal simply hearing a detonation at great distance are not considered harassment and are not analyzed further.

3.2.4 Summary

Extensive modeling of the potential impact of shock test detonations on marine mammals has been completed (Appendices C and D). Conservative criteria for lethal take, injurious take, and harassment have been defined. For lethal take, the criterion is the onset of extensive lung injury (i.e., 1% mortality among animals affected). For injurious take, the criterion is the 10% eardrum rupture contour at the sea bottom. For

harassment, an acoustic discomfort criterion has been developed. **Table 3-1** summarizes the maximum range and corresponding area for each take category.

3.3 INCIDENTAL TAKE CALCULATIONS

With the establishment of the safety range within a 3.79 km (2.05 nmi) radius from the detonation point, marine mammals could be killed or injured only if they were present within the safety range but not detected during pre-detonation monitoring. The following method was used to conservatively estimate how many animals could be affected:

1. Maximum ranges for lethal and injurious takes and harassment were calculated as summarized above. These ranges were used to define concentric circles around the detonation point (**Figure 3-3**), and to calculate the area within each circle (**Table 3-1**).

2. Mean densities of each species were multiplied by the area of the lethal, injury, and harassment ranges to estimate the number of mammals affected "without mitigation" for a single detonation. Mean densities were taken from Section 2.2 and are based on 1995 aerial survey counts adjusted for submerged and undetected individuals.

3. Mitigation effectiveness was estimated for each species, taking into account the probability of detection by aerial and surface observers and passive acoustic monitoring (see Appendix B). For lethal and injurious take, the "without mitigation" numbers for each species were then multiplied by (1 minus mitigation effectiveness), which is the probability of not detecting that species during pre-detonation monitoring. The resulting values are the expected number of undetected animals of each species within the lethal and injury ranges.

4. For harassment, the "with mitigation" numbers were assumed to be equal to the "without mitigation" numbers, because only animals outside the safety range would be affected.

5. The lethal, injury, and harassment estimates for a single detonation were multiplied by five to account for the five detonations that would occur during SEAWOLF shock testing. Species historically present at or near each area but not seen during 1995 aerial surveys were each assigned a harassment take of one individual per five detonations. This includes, for example, species such as the dwarf and pygmy sperm whales (*Kogia* spp.) which appear frequently in stranding reports from the southeastern U.S. but are rarely seen at sea. This value is similar to those calculated for the least abundant species observed during 1995 aerial surveys. The results were totalled and then rounded up to the nearest whole number.

There are several key assumptions. First, it was assumed that marine mammal densities during shock testing would be similar to those during 1995 aerial surveys. Although this may or may not hold true, the 1995 observations are the best

Table 3-1. Maximum ranges and corresponding areas for various categories of incidental take. Ranges are based on calculations in Appendices C and D as indicated. Areas were calculated using πr^2, where r = maximum range.

Take Category and Criterion	Maximum Range		Area Within Range	
	m (ft)	km (nmi)	Original Calculation km^2 (nmi^2)	After Subtracting Inner Range(s)[a] km^2 (nmi^2)
Lethal Take:				
Extensive lung hemorrhage (1% mortality) (Appendix C)	1,524 m (5,000 ft)	1.52 km (0.82 nmi)	7.30 km^2 (2.13 nmi^2)	7.30 km^2 (2.13 nmi^2)
Injurious Take:				
10% eardrum rupture at 152 m (500 ft) (Appendix C)	3,792 m (12,440 ft)	3.79 km (2.05 nmi)	45.16 km^2 (13.15 nmi^2)	37.86 km^2 (11.02 nmi^2)
Harassment:				
Acoustic discomfort (Appendix D)	11,111 m (36,456 ft)	11.11 km (6.00 nmi)	387.86 km^2 (112.93 nmi^2)	342.70 km^2 (99.78 nmi^2)

[a] Injury and harassment areas were corrected to avoid double-counting different take categories. For example, if an animal were killed, it should not also be counted as injured. The area of the lethal range was subtracted from the area of the injury range. Similarly, the uncorrected area of the injury range was subtracted from the harassment range.

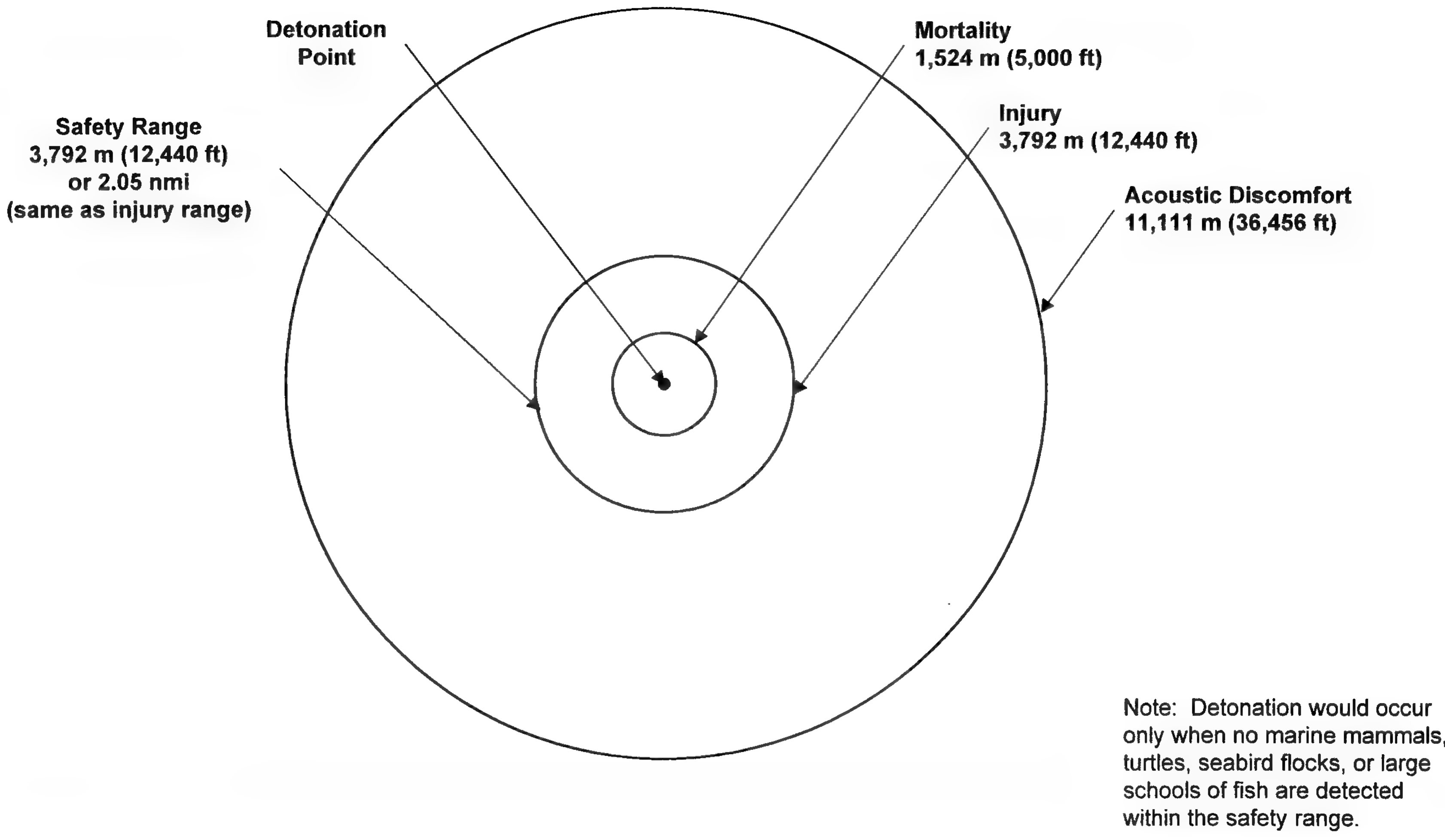


Figure 3-3. Maximum horizontal ranges for mortality, injury, and acoustic discomfort in relation to the safety range for mitigation efforts.

quantitative data available for both areas. Also, other species with historical sightings from the Mayport or Norfolk areas were taken into account by assuming one individual of each of these species would experience acoustic discomfort. Second, it was assumed that the mean density for a whole area (Mayport or Norfolk) can be used to predict the expected number of animals that would occur within a small test site. This assumption overestimates impacts, because the abundance of marine mammals is patchy within both areas and the Navy proposes to select an operationally suitable test site with the lowest possible density of marine mammals and turtles (i.e., much lower than the mean density for the area as a whole). Finally, the estimates of detectability (mitigation effectiveness) for each species are assumed to be accurate. These numbers were developed through a logical process that included consultation with and review by marine mammal experts (see Appendix B).

Based on these assumptions and calculations, estimates of potential lethal and injurious incidental take and harassment are provided **Table 3-2** for Mayport and **Table 3-3** for Norfolk. Each table provides estimates for a single detonation, with and without mitigation, and for five detonations with mitigation. Shock testing would only be conducted *with mitigation*; the without mitigation numbers are provided for comparison and evaluation of mitigation effectiveness. **Table 3-4** summarizes potential incidental take and mitigation effectiveness (for lethal and injurious takes) for Mayport and Norfolk for all five detonations. Overall mitigation effectiveness would be about 93% for both Mayport and Norfolk.

3.3.1 Mayport Area

Table 3-2 summarizes the incidental take calculations for the Mayport area. Estimated totals for five detonations "with mitigation" are 1 lethal take, 5 injurious takes, and 570 harassment takes. It is very unlikely that even one individual would be killed or injured by a single detonation at the Mayport area. Species most likely to be affected at Mayport are pantropical spotted dolphin, Risso's dolphin, and Atlantic spotted dolphin.

The only endangered marine mammal species potentially killed or injured at Mayport is the sperm whale. The estimated numbers are 0.01 or less per detonation for both mortality and injury; totals for five detonations are 0.01 mortalities and 0.05 injuries. Therefore, it is highly unlikely that any sperm whales would be killed or injured by the five detonations. Sperm whales produce distinctive low-frequency clicked vocalizations (Jefferson et al., 1993) and are very likely to be detected (if present) using the passive acoustic monitoring system described in Section 4.0 (Tyack, 1996). The other endangered marine mammals (blue, fin, humpback, sei, and northern right whales) are baleen whales which generally inhabit northern feeding grounds during the period proposed for shock testing and which were never observed off Mayport during the 1995 aerial census efforts. Therefore, it is assumed none would be killed or injured by the proposed action.

3.3.2 Norfolk Area

Table 3-3 summarizes the incidental take calculations for the Norfolk area. Estimated totals for five detonations "with mitigation" are 8 lethal takes, 38 injurious takes, and 4,819 harassment takes. Species that could have a total of more than one individual

Table 3-2. Estimates of potential marine mammal lethal and injurious take and harassment from shock testing at the Mayport area, with and without mitigation. Shock testing would only be conducted "with mitigation," including no testing in April at Mayport. Numbers are given to two decimal places to indicate the relative risk to various species; totals for five detonations are rounded up at the end of the table. Species historically present in the region but not seen at Mayport during 1995 aerial surveys (indicated by * next to the species name) are assigned five-detonation totals of 0 individuals for lethal and injurious take and 1 individual for harassment.

Species	MAYPORT AREA SINGLE DETONATION WITHOUT MITIGATION[a] No. of Animals Within Specified Range			Mitigation Effectiveness[b] (Mortality and Injury Only)	MAYPORT AREA SINGLE DETONATION WITH MITIGATION[c] No. of Undetected Animals Within Specified Range			MAYPORT AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment		Lethal	Injury	Harassment	Lethal	Injury	Harassment
BALEEN WHALES										
* Blue whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
* Bryde's whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Fin whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
* Humpback whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
* Minke whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Northern right whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
* Sei whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
TOOTHED WHALES AND DOLPHINS										
Atlantic spotted dolphin	0.21	1.10	9.95	0.93	0.01	0.08	9.95	0.08	0.40	49.73
Bottlenose dolphin	0.21	1.11	10.07	0.93	0.02	0.08	10.07	0.08	0.40	50.37
Bottlenose/Atlantic spotted dolphin	0.07	0.37	3.36	0.93	0.01	0.03	3.36	0.03	0.14	16.79
Clymene/spinner/striped dolphin	0.05	0.27	2.45	0.96	<0.01	0.01	2.45	0.01	0.05	12.27
Pantropical spotted dolphin	0.63	3.27	29.58	0.93	0.05	0.24	29.58	0.23	1.19	147.89
Risso's dolphin	0.48	2.50	22.60	0.93	0.03	0.18	22.60	0.17	0.90	113.02
Sperm whale (E)	0.01	0.06	0.52	0.81	<0.01	0.01	0.52	0.01	0.05	2.58
Spinner dolphin	0.14	0.71	6.46	0.96	0.01	0.03	6.46	0.02	0.13	32.29
Unidentified dolphin	0.52	2.68	24.28	0.93	0.04	0.19	24.28	0.19	0.97	121.42

Table 3-2. (Continued).

Species	MAYPORT AREA SINGLE DETONATION WITHOUT MITIGATION[a] No. of Animals Within Specified Range			Mitigation Effectiveness[b] (Mortality and Injury Only)	MAYPORT AREA SINGLE DETONATION WITH MITIGATION[c] No. of Undetected Animals Within Specified Range			MAYPORT AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment		Lethal	Injury	Harassment	Lethal	Injury	Harassment
* Blainville's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Clymene dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Common dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Cuvier's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Dwarf sperm whale	0	0	0.20	NA	0	0	0.20	0	0	1
* False killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Fraser's dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Gervais' beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Melon-headed whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Pilot whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Pygmy killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Pygmy sperm whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Rough-toothed dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Striped dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* True's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
TOTAL	2.33	12.07	109.27	0.93[d]	0.16	0.85	109.27	**1** (0.82)	**5** (4.23)	**570** (569.36)

(E) = endangered species. NA = not applicable. * = species historically present in the region but not seen at the Mayport area during 1995 aerial surveys.

a "Without mitigation" numbers are based on adjusted mean densities (see Section 2.2) for May through September at Mayport, scaled to the area within the range for lethal take (7.30 km^2 or 2.13 nmi^2), injurious take (37.87 km^2 or 11.03 nmi^2), or harassment (342.70 km^2 or 99.78 nmi^2).

b Mitigation effectiveness is the probability that an individual, if present, would be detected. It takes into account aerial, surface, and passive acoustic monitoring (see Appendix B).

c For lethal and injurious take, "with mitigation" numbers are equal to the "without mitigation" numbers times (1 minus mitigation effectiveness). For harassment, there is no difference between "with mitigation" and "without mitigation" numbers.

d Overall mitigation effectiveness for lethal and injurious take was calculated as 1 minus (total with mitigation/total without mitigation).

Table 3-3. Estimates of potential marine mammal lethal and injurious take and harassment from shock testing at the Norfolk area, with and without mitigation. Shock testing would only be conducted "with mitigation." Numbers are given to two decimal places to indicate the relative risk to various species; totals for five detonations are rounded up at the end of the table. Species historically present in the region but not seen at Norfolk during 1995 aerial surveys (indicated by * next to the species name) are assigned five-detonation totals of 0 individuals for lethal and injurious take and 1 individual for harassment.

Species	NORFOLK AREA SINGLE DETONATION WITHOUT MITIGATION[c] No. of Animals Within Specified Range			Mitigation Effectiveness[b] (Mortality and Injury Only)	NORFOLK AREA SINGLE DETONATION WITH MITIGATION[c] No. of Undetected Animals Within Specified Range			NORFOLK AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment		Lethal	Injury	Harassment	Lethal	Injury	Harassment
BALEEN WHALES										
Fin whale (E)	0.21	1.10	9.93	0.89	0.02	0.12	9.93	0.12	0.60	49.65
Humpback whale (E)	0.01	0.02	0.22	0.89	<0.01	<0.01	0.22	<0.01	0.01	1.08
Minke whale	0.02	0.10	0.86	0.43	0.01	0.05	0.86	0.05	0.27	4.32
Sei whale (E)	0.01	0.05	0.43	0.89	<0.01	0.01	0.43	0.01	0.03	2.16
Sei or Bryde's whale	0.01	0.02	0.22	0.89	<0.01	<0.01	0.22	<0.01	0.01	1.08
Unidentified *Balaenoptera* sp.	0.05	0.29	2.59	0.89	0.01	0.03	2.59	0.03	0.16	12.95
Unidentified baleen whale	0.02	0.09	0.86	0.89	<0.01	0.01	0.86	0.01	0.05	4.32
* Blue whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
* Bryde's whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Northern right whale (E)	0	0	0.20	NA	0	0	0.20	0	0	1
TOOTHED WHALES AND DOLPHINS										
Atlantic spotted dolphin	3.79	19.65	177.87	0.93	0.28	1.43	177.87	1.37	7.13	889.34
Bottlenose dolphin	2.36	12.26	110.95	0.93	0.17	0.89	110.95	0.86	4.44	554.76
Bottlenose/Atl. spotted dolphin	0.29	1.53	13.82	0.93	0.02	0.11	13.82	0.11	0.55	69.07
Clymene/spinner/striped dolphin	1.13	5.84	52.88	0.96	0.04	0.21	52.88	0.20	1.06	264.43
Common dolphin	1.42	7.39	66.92	0.93	0.10	0.54	66.92	0.52	2.68	334.58
Cuvier's beaked whale	0.02	0.09	0.86	0.43	0.01	0.05	0.86	0.05	0.27	4.32
Pantropical spotted dolphin	2.00	10.38	93.90	0.93	0.15	0.75	93.90	0.72	3.76	469.49
Pilot whale	6.32	32.82	297.02	0.93	0.46	2.38	297.02	2.29	11.90	1485.11
Risso's dolphin	0.55	2.84	25.69	0.93	0.04	0.21	25.69	0.20	1.03	128.44
Sperm whale (E)	0.04	0.19	1.73	0.81	0.01	0.04	1.73	0.04	0.18	8.63
Spinner dolphin	0.28	1.48	13.38	0.96	0.01	0.05	13.38	0.05	0.27	66.92
Striped dolphin	0.11	0.57	5.18	0.96	<0.01	0.02	5.18	0.02	0.10	25.90
Unidentified dolphin	1.77	9.21	83.32	0.93	0.13	0.67	83.32	0.64	3.34	416.61

Table 3-3. (Continued).

Species	NORFOLK AREA SINGLE DETONATION WITHOUT MITIGATION[c] No. of Animals Within Specified Range			Mitigation Effectiveness[b] (Mortality and Injury Only)	NORFOLK AREA SINGLE DETONATION WITH MITIGATION[c] No. of Undetected Animals Within Specified Range			NORFOLK AREA FIVE DETONATIONS WITH MITIGATION No. of Undetected Animals Within Specified Range		
	Lethal	Injury	Harassment		Lethal	Injury	Harassment	Lethal	Injury	Harassment
Unidentified small whale	0.02	0.12	1.08	0.93	<0.01	0.01	1.08	0.01	0.04	5.40
* Atlantic white-sided dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Blainville's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Clymene dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Dwarf sperm whale	0	0	0.20	NA	0	0	0.20	0	0	1
* False killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Fraser's dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Gervais' beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Harbor porpoise	0	0	0.20	NA	0	0	0.20	0	0	1
* Killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Melon-headed whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Northern bottlenose whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Pygmy killer whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Pygmy sperm whale	0	0	0.20	NA	0	0	0.20	0	0	1
* Rough-toothed dolphin	0	0	0.20	NA	0	0	0.20	0	0	1
* Sowerby's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
* True's beaked whale	0	0	0.20	NA	0	0	0.20	0	0	1
PINNIPEDS										
* Harbor seal	0	0	0.20	NA	0	0	0.20	0	0	1
TOTAL	20.43	106.04	963.71	0.93[d]	1.46	7.58	963.71	**8** (7.30)	**38** (37.88)	**4,819** (4818.55)

(E) = endangered species. NA = not applicable. * = species historically present in the region but not seen at the Norfolk area during 1995 aerial surveys.

a "Without mitigation" numbers are based on adjusted mean densities (see Section 2.2) for April through September at Norfolk, scaled to the area within the range for lethal take (7.30 km^2 or 2.13 nmi^2), injurious take (37.87 km^2 or 11.03 nmi^2), or harassment (342.70 km^2 or 99.78 nmi^2).

b Mitigation effectiveness is the probability that an individual, if present, would be detected. It takes into account aerial, surface, and passive acoustic monitoring (see Appendix B).

c For lethal and injurious takes, "with mitigation" numbers are equal to the "without mitigation" numbers times (1 minus mitigation effectiveness). For harassment, there is no difference between the "with mitigation" and "without mitigation" numbers.

d Overall mitigation effectiveness for lethal and injurious take was calculated as 1 minus (total with mitigation/total without mitigation).

Table 3-4. Summary and comparison of Mayport and Norfolk areas with respect to potential incidental take and mitigation effectiveness. Data are from the last row of Tables 3-2 and 3-3.

Incidental Take Category	Description	Mayport	Norfolk
Lethal	Number of individuals potentially killed from 5 detonations	1	8
Injurious	Number of individuals potentially injured from 5 detonations	5	38
Harassment	Number of individuals potentially experiencing acoustic discomfort from 5 detonations	570	4,819
Mitigation effectiveness for lethal and injurious take	Percentage of individuals present within safety range that would be detected by combination of aerial, surface, and passive acoustic monitoring	93%	93%

killed as a result of five detonations are pilot whale and Atlantic spotted dolphin. Species that could have more than one individual injured as a result of five detonations are pilot whale, Atlantic spotted dolphin, bottlenose dolphin, pantropical spotted dolphin, and common dolphin.

In contrast to Mayport, several endangered whale species could be affected at the Norfolk area. The highest numbers are for fin whale, which was the most abundant baleen whale at the area during 1995 aerial surveys. It is unlikely that a fin whale would be killed (0.12 individuals), but more likely that one would be injured (0.60 individuals). For the humpback, sei, and sperm whales, the lethal take estimates per detonation are 0.01 individuals or fewer, indicating it is very unlikely that individuals of these species would be killed. Two other endangered species, the blue whale and the northern right whale, generally inhabit northern feeding grounds during the period proposed for shock testing and were never observed off Norfolk during the 1995 aerial census efforts; therefore, they are assumed to have no lethal or injurious takes.

3.4 POTENTIAL IMPACTS ON MARINE MAMMAL HABITAT

Potential changes to marine mammal habitat offshore Mayport and Norfolk which are considered below are (1) contact with the chemical by-products of the explosion; and (2) other alteration of the local environment as a result of the detonations.

3.4.1 Chemical By-Products

A conventional Navy explosive (HBX-1, High Blast eXplosive) is proposed for use in the shock test. By weight, HBX-1 consists of the following components: cyclotrimethylene trinitramine - 39.32%; trinitrotoluene - 37.76%; aluminum powder - 17.10%; wax - 4.57%; and miscellaneous fillers - 1.25%.

Products of an explosion conducted in deep water are generally confined to a thin, circular area (the "surface pool") created by the upwelling resulting from rising gas bubbles. Young (1995), analyzing the surface pool created by the detonation of a 4,536 kg (10,000 lb) HBX-1 charge at 30 m (100 ft) in a water depth of 152 m (500 ft), characterized the explosion as follows:

■ Radius of surface pool (maximum)	457 m (1,500 ft)
■ Depth of surface pool (approximate)	12 m (39 ft)
■ Pool volume	7.82 x 10^6 m^3 (276 x 10^6 ft^3)
■ Time for dispersal of chemical by-products	68 min

These calculations are considered representative of a stabilized surface pool (i.e., when the pool becomes passive and relatively stable and the energy of the explosion has dissipated). Chemical composition of the surface pool predominantly includes gases with limited amounts of carbon and/or aluminum oxide solids. It is estimated that only 10% of the gases are dissolved in seawater, with the remaining 90% being released into the atmosphere (Young, 1995).

Table 3-5 summarizes the explosion by-products in seawater. The table compares the concentrations of various constituents with water quality criteria developed

Table 3-5. Predicted concentrations of explosion products in seawater, compared with permissible concentrations (Adapted from: Young, 1995). Predicted concentrations are for the surface pool at the time of stabilization. Permissible concentrations are based on reference standards for marine life (U.S. Environmental Protection Agency, 1986; Suter and Rosen, 1988). In cases where marine life criteria have not been established, values for humans were used (Sittig, 1985).

Explosion Product	Predicted Concentration (mg/L)	Permissible Concentration (mg/L)
Carbon dioxide (CO_2)	0.00113	1.0[a]
Carbon monoxide (CO)	0.0127	0.552
Ammonia (NH_3)	0.001	0.092[b]
Ethane (C_2H_6)	0.00203	120
Propane (C_3H_8)	0.000586	120
Hydrogen cyanide (HCN)	0.000129	0.001[b] 0.036[c]
Methane (CH_4)	0.0000546	120
Methyl alcohol (CH_3OH)	0.00000446	3.60
Formaldehyde (CH_2O)	0.00000221	0.0414
Carbon (C)	0.0621	NA
Acetylene (C_2H_2)	0.00000285	73
Phosphine (PH_3)	0.00000394	0.0055
Aluminum oxide (Al_2O_3)	0.189	NA

[a] 1.0 mg/L produces avoidance by fish.
[b] Water quality criterion from U.S. Environmental Protection Agency (1986).
[c] Maximum acceptable toxicant concentration for fish exposed to cyanide (Suter and Rosen, 1988).

to protect marine or human life. The U.S. Environmental Protection Agency (1986) has published water quality criteria for ammonia and cyanide, but not for the other explosion products. The two solids, carbon and aluminum oxide, are both found in nature and are not hazardous materials. For the other products, criteria to protect marine life (Suter and Rosen, 1988) or humans (Sittig, 1985) were used. All of the predicted concentrations are below the criteria, indicating no hazard to marine life. Because of continued dispersion and mixing, there would be no buildup of explosion products in the water column. Therefore, it is extremely unlikely that any impacts to marine mammals or their prey would occur as a result of exposure to the chemical by-products of the detonations.

Table 3-6 summarizes the concentrations of airborne explosion by-products expected from the proposed detonations. There are no air quality standards developed specifically for underwater explosions. For comparison, limits used by the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and the National Institute for Occupational Safety and Health (NIOSH) can be used. Relevant standards include the Ceiling Concentration (CL), which cannot be exceeded at any time; and the Short-Term Exposure Limit (STEL), which is usually a 15-minute time-weighted average. Limits are not given for asphyxiants, which are non-toxic gases that exclude oxygen from the lungs when present in high concentrations. All of the predicted initial concentrations (except for carbon monoxide and ammonia) are below the OSHA, ACGIH, and NIOSH limits. The initial concentrations would disperse rapidly in the atmosphere; all predicted concentrations would be well below the limits at 305 m (1,000 ft) downwind, a point which would be reached within a few minutes after detonation depending on wind speed (e.g., within 2 minutes in a 5-kt wind). Because of the low initial concentrations and rapid dispersion of explosion products, there would not be any risk to marine mammals or other sea life in the area.

In conclusion, the proposed action would result in no significant impacts to marine mammal habitat due to explosion by-products, either dispersed in the water column or present in the atmosphere.

3.4.2 Other Habitat Alteration

Prey species are a component of the marine mammal habitat which would be affected by the proposed detonations. However, significant impacts to marine mammal habitat are unlikely because (1) the proposed areas are not known marine mammal feeding grounds, and (2) only a small area would be affected and prey populations would be rapidly replenished (in a matter of hours) through reproduction and turbulent mixing with adjacent waters. There would be no loss or permanent modification to marine mammal habitat from the proposed action.

Table 3-6. Atmospheric concentrations of explosion products compared with atmospheric exposure standards (Adapted from: Young, 1995). Concentrations are based on a 4,536 kg (10,000 lb) HBX-1 charge detonated at 30 m (100 ft) below the sea surface.

Explosion Product	Concentration (ppm)			Exposure Standard (ppm except where noted)		
	Initial	305 m (1,000 ft) Downwind	1,524 m (5,000 ft) Downwind	OSHA PEL	ACGIH TLV	NIOSH REL
Carbon dioxide (CO_2)	37.9	1.2	0.107	--[a]	STEL: 30,000	CL: 30,000
Carbon monoxide (CO)	672	21.2	1.90	--[a]	STEL: 400	CL: 200
Ammonia (NH_3)	86.4	2.73	0.245	--[a]	STEL: 35	CL: 50
Ethane (C_2H_6)	100	3.16	0.283	Asphyxiant	Asphyxiant	Asphyxiant
Propane (C_3H_8)	19.6	0.619	0.0555	--[a]	Asphyxiant	--
Hydrogen cyanide (HCN)	7.06	0.223	0.0200	--[a]	CL: 10	CL: 5 mg CN/m^3/10M
Methane (CH_4)	5.03	0.159	0.0142	Asphyxiant	Asphyxiant	Asphyxiant
Methyl alcohol (CH_3OH)	0.205	0.0065	0.0006	--[a]	STEL: 250	CL: 800/15M
Formaldehyde (CH_2O)	0.108	0.0034	0.0003	--[a]	--[a]	--
Acetylene (C_2H_2)	0.161	0.0051	0.0005	CL: 2,500	Asphyxiant	CL: 2,500
Phosphine (PH_3)	0.171	0.0054	0.0005	--[a]	STEL: 1	--

Abbreviations:
OSHA = Occupational Safety and Health Administration; PEL = permissible exposure limit.
ACGIH = American Conference of Governmental Industrial Hygienists; TLV = threshold limit value.
NIOSH = National Institute for Occupational Safety and Health; REL = recommended exposure limit.
CL = ceiling concentration; STEL = short-term exposure limit.

[a] The only limit specified is a time-weighted average for an 8-hr day, 40-hr work week. This would not be relevant to the proposed detonations.

4.0 MITIGATION MEASURES AND INTERAGENCY COORDINATION

Although this Request for Letter of Authorization deals exclusively with the potential incidental take of marine mammals, mitigation and monitoring efforts apply to sea turtles, flocks of seabirds, and schools of fish as well. Interagency coordination, involving representatives from the Navy and NMFS (Northeast Fisheries Science Center and Southeast Fisheries Science Center), would ensure that shock tests proceed in the safest possible manner.

A detailed marine mammal and sea turtle mitigation plan has been developed to reduce or eliminate the effects of shock testing on marine life. The plan includes the same type of mitigation and monitoring efforts that were used successfully during the shock trial of the USS JOHN PAUL JONES in 1994 off the coast of southern California where observed marine mammal population densities are about 3 times greater than at the Norfolk area and about 25 times higher than at the Mayport area (Department of the Navy, 1993). Those shock trial operations included two 4,536 kg (10,000 lb) detonations and resulted in no deaths or injuries of marine mammals (Naval Air Warfare Center, 1994).

Potential areas for SEAWOLF shock testing have been evaluated in the Alternatives section of the DEIS based on the Navy's operational requirements. The analysis showed that only the Mayport and Norfolk areas meet all of the Navy's operational requirements and that the two areas are rated as nearly equal. Portions of the Norfolk area were excluded based on environmental considerations (proposed Norfolk Canyon National Marine Sanctuary and shipwrecks). The schedule for testing at Mayport was shifted to avoid high turtle densities (i.e., no testing in April at Mayport). Finally, impact analysis in the DEIS was used to identify a preferred alternative area (Mayport) based on the lower density of marine mammals.

The mitigation plan would build upon these previous efforts to avoid or further reduce potential environmental impacts. It would select one primary and two secondary test sites where marine mammal and turtle abundances are the lowest, based on the results of aerial surveys to be conducted immediately prior to the first detonation. This would ensure that the final test site selected for shock testing poses the least risk to the marine environment. Pre-detonation monitoring would be conducted prior to each detonation to ensure that the test site is free of marine mammals, turtles, large schools of fish, and flocks of seabirds. Finally, post-detonation monitoring would be conducted to determine the effectiveness of the mitigation efforts, by using a Marine Animal Recovery Team (MART) and aerial observers to monitor the test site and surrounding waters for injured or dead animals after each detonation.

4.1 TERMINOLOGY

The concept of a ***safety range***, as presented in Section 3.1, is integral to the mitigation plan. Establishment of a 3.8 km (2.05 nmi) safety range around the detonation point has taken into consideration the estimated ranges for various levels of injury and/or mortality associated with detonation of a 4,536 kg (10,000 lb) explosive. Based on

analyses presented in Appendix C, the maximum distance for the remote possibility of auditory system injury (i.e., eardrum rupture) to a marine mammal is 3.8 km (2.05 nmi) from the detonation point.

For mitigation monitoring purposes, a 1.8 km (0.95 nmi) ***buffer zone*** has also been added to the 3.8 km (2.05 nmi) safety range to accommodate the possible movement of animals towards the safety range. Specifically, the area encompassed within a 5.6 km (3 nmi) radius from the detonation point would be monitored in an effort to detect any marine mammals or turtles approaching the 3.8 km (2.05 nmi) safety range, as detailed below.

In the following sections, the term ***survey*** is used to refer to site selection activities, whereas ***monitoring*** refers to pre-detonation site clearance and post-detonation activities to locate and identify marine mammals or turtles.

4.2 WEATHER LIMITATIONS

Weather which supports the ability to sight even small marine life (e.g., sea turtles) is essential for mitigation measures to be effective. Winds, visibility, and the surface conditions of the ocean are the most critical factors affecting mitigation operations for the SEAWOLF shock test. High winds typically promote increases in wave height and "white cap" conditions, both of which limit an observer's ability to locate surfacing marine mammals and to differentiate between surfacing marine mammals and white caps. Based on the Navy's experience during the shock trial of the USS JOHN PAUL JONES (Naval Air Warfare Center, 1994), weather conditions begin to adversely impact mitigation effectiveness in a sea state of Beaufort 5 (i.e., wind velocity 17-21 kt). Similarly, the results of cetacean census efforts off the California coast have also supported the effective conduct of surveys in weather conditions up to and including Beaufort 4; however, sighting rates are appreciably different in a comparison of Beaufort 0 to 2 and rough Beaufort 3 to 4 conditions (Barlow, 1995; Carretta et al., 1995; Forney et al., 1995). As a result, SEAWOLF shock testing would not be conducted in a sea state exceeding Beaufort 4 (i.e., wind velocity >16 kt). Visibility is also a critical factor, not only for observation capabilities but also for safety-of-flight issues. A minimum ceiling of 305 m (1,000 ft) and 1.85 km (1 nmi) visibility must be available to support mitigation and safety-of-flight concerns.

The aerial surveys conducted within the Mayport and Norfolk areas during the months of April through September 1995 were completed in a sea state of Beaufort 3 (i.e., wind velocity 7-10 kt) or less. These conditions ensured acceptable sighting conditions for the survey team which included two observers and a data logger. In contrast, the full mitigation team would consist of three observers in each aircraft, six or seven shipboard observers (four with high powered binoculars), and the Marine Mammal Acoustic Tracking System (MMATS) team. This complement of trained marine mammal observers would provide five times the visual detection capability used during the 1995 aerial surveys. The increased number of observers would ensure effective mitigation during the shock test in a sea state of Beaufort 4 (i.e., wind velocity 11-16 kt).

4.3 MITIGATION COMPONENTS/TEAMS

The mitigation plan includes three components: (1) aerial surveys/monitoring; (2) shipboard monitoring from the operations vessel and the Marine Animal Recovery Team (MART) vessel; and (3) passive acoustic monitoring using the Marine Mammal Acoustic Tracking System (MMATS). Aerial and shipboard monitoring teams would identify and locate animals on the surface, whereas the acoustic monitoring team would detect and locate calls from submerged animals. The lines of communication between the various monitoring teams are outlined in **Figure 4-1** and discussed in the following section.

4.3.1 Aerial Survey/Monitoring Team

The aerial team would include one aircraft with three marine biologists aboard. Each biologist would be experienced in marine mammal surveying and would be familiar with species that may occur in the area. A backup aircraft with additional biologists would be available to support the shock test. The backup aircraft would relieve the primary aircraft for post-detonation monitoring. In consideration of safety-of-flight issues, only one aircraft would be allowed in the airspace over the test site at any one time (Naval Air Warfare Center, 1994). Each aircraft would have a data recorder who would be responsible for relaying the location, species, and number of animals sighted by aircraft personnel to the Lead Scientist onboard the operations vessel. The Lead Scientist would be responsible for recording all sightings within the test site and relaying this information to the Shock Test Director and the Officer in Tactical Command (OTC). The aerial monitoring team would also identify to the MART vessel any large accumulations of *Sargassum* that should be investigated for the presence of juvenile sea turtles.

Standard line transect aerial surveying methods, as developed by the NMFS (Blaylock, 1994; Hoggard, 1994; Mullin, 1994), would be used for all mitigation aerial surveys and monitoring. All aerial surveys and aerial monitoring would be conducted along transects spaced 1.85 km (1 nmi) apart and flown at an altitude of 198 m (650 ft) and a speed of 110 kt. Although the 1995 aerial surveys (Department of the Navy, 1995a) off Norfolk and Mayport were flown at an altitude of 229 m (750 ft), an altitude of 198 m (650 ft) was chosen for the mitigation aerial surveys and monitoring to increase visual detection of sea turtles. Observers on both sides of the aircraft would scan a swath of sea surface which would be limited only by the effective angle of view from the aircraft's viewing ports or windows, and sea state. Based on the shock trial of the USS JOHN PAUL JONES (Naval Air Warfare Center, 1994) and prior survey efforts off Mayport and Norfolk, aerial observers are expected to have good to excellent sighting capability to 0.9 km (0.5 nmi) on either side of the aircraft within the weather limitations noted previously. Observed marine mammals and turtles would be identified to species or the lowest possible taxonomic level, and their relative positions recorded. Detonations would only occur no earlier than three hours after sunrise and no later than three hours prior to sunset to ensure adequate daylight for pre- and post-detonation monitoring.

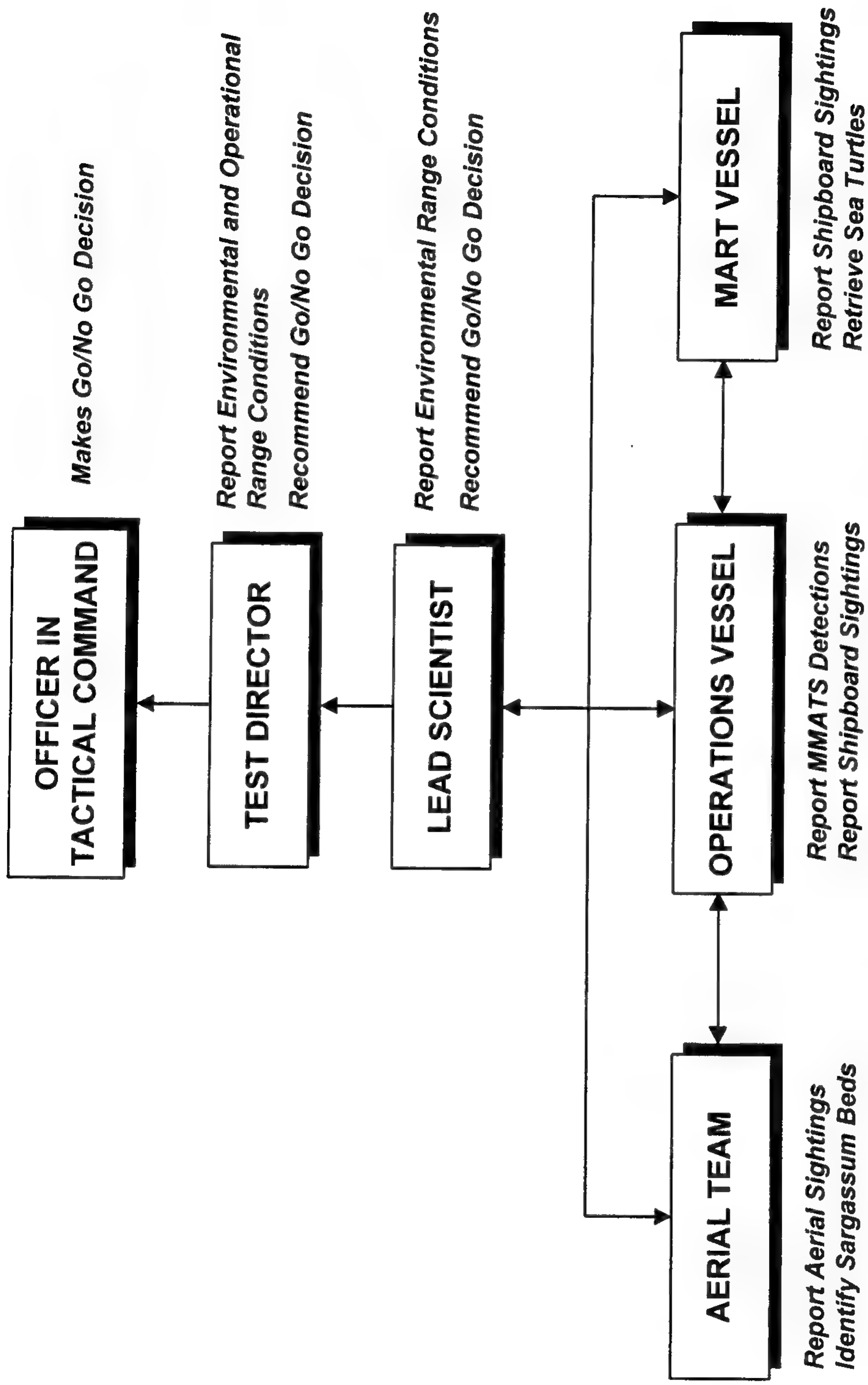


Figure 4-1. Lines of communication between the aerial monitoring team, operations vessel, and MART vessel.

4.3.2 Shipboard Monitoring Teams

Shipboard monitoring would be staged from surface craft participating in the shock test, including the operations vessel and the MART vessel. Each vessel would be outfitted with two sets of 25X binoculars. The operations vessel would accommodate three marine biologists experienced in shipboard surveys and who are familiar with the marine life of the area. Two biologists would monitor the test site with the vessel-mounted (i.e., installed on the bridge wing or deckhouse of the operations vessel) 25X binoculars or hand-held binoculars. The 25X binoculars would allow the biologists to sight surfacing mammals from as far as 11.1 km (6 nmi). The third biologist would rotate stations with the other two biologists to allow each an opportunity to rest their eyes. The positioning of the shipboard monitoring teams would allow 360° overlapping coverage. Each biologist would report all sightings to the Lead Scientist located on the operations vessel. As with all aerial monitoring team sightings, the Lead Scientist would be responsible for recording all sightings made by the shipboard monitoring team. Each sighting would be recorded and plotted (i.e., latitude, longitude) relative to the point of detonation. The species and abundance of animals sighted would also be recorded. The Lead Scientist would ensure that the OTC is aware of all animals in or approaching the test site.

In addition to the operations vessel, the MART vessel would assist in pre-detonation monitoring using 25X binoculars and hand-held binoculars. The MART vessel would also have three marine biologists aboard with shipboard survey experience for waters of the proposed test. The MART vessel biologists would follow the same monitoring rotation and reporting protocol (i.e., biologist reporting to the Lead Scientist; Lead Scientist reporting to the Shock Test Director and OTC).

A small, fast boat (e.g., Zodiac or equivalent) would be deployed from the MART vessel to investigate selected beds of *Sargassum* for the presence of sea turtles. Generally, *Sargassum* beds attract smaller juvenile turtles which may be difficult to capture. If necessary, small turtles would be removed from the algae beds using a breakaway mesh net attached to an aluminum frame. The aluminum frame and net would be positioned via a long aluminum pole in front of the turtle. After the turtle swims into the net, a nylon drawstring would close the net which would then be detached from the frame and pulled onboard the Zodiac. Larger turtles swimming within the test site would be removed using a larger aluminum frame and net positioned from the MART vessel. All retrieved turtles would be temporarily held in a sun-protected area on the deck of the MART vessel until after the detonation. MART biologists would also tag and record any dead animals found in and near the test site prior to each detonation so that they are not counted as deaths caused by shock testing.

MART personnel would remain on station for a period of 48 hours after each detonation to monitor the test site and surrounding waters for injured or dead animals. If any animals are observed in the general area during the 48 hours post-detonation, the location, abundance, species, and behavior would be recorded. Depending upon their size, any injured or dead animals would be retrieved in an attempt to determine the cause of injury or death. The MART vessel would be assisted by the aerial monitoring team for three hours per day during the two days following each detonation. The aerial team would assist in the location of animals in the area and would direct the MART vessel to any sighted animals in the area that appear to be injured or dead.

4.3.3 Marine Mammal Acoustic Tracking System

The Marine Mammal Acoustic Tracking System (MMATS) is a portable, rapidly deployable signal processing system which would be used to detect and localize sources of transient acoustic signals produced by vocalizing marine mammals. The MMATS was successfully used during the shock trial of the USS JOHN PAUL JONES (Naval Air Warfare Center, 1994). The system would consist of 10 to 15 moored acoustic receivers deployed from the MART vessel or, if necessary, from aircraft. The system includes a passive sonar processing mode. The positions of transient acoustic sources are determined by time-delay-of-arrival analysis; the system is capable of localizing to within 0.46 km (0.25 nmi) of the actual position of the source. Therefore, if an animal is acoustically detected within 4.3 km (2.3 nmi) of the detonation point, it would be assumed that the animal is within the 3.8 km (2.05 nmi) safety range; under these circumstances, no detonation would occur until it is confirmed that the animal's position is outside the 3.8 km (2.05 nmi) safety range. The MMATS configuration is shown in **Figure 4-2**.

The MMATS would monitor the frequency bandwidths between 15 Hz and 10 kHz (15 to 10,000 Hz). This frequency range covers the vast majority of calls produced by baleen and toothed whales, including the six species of endangered whales which may be found within the Mayport and Norfolk offshore areas [i.e., blue whale (*Balaenoptera musculus*): 10-30, 50-60, and 6,000-8,000 Hz; fin whale (*Balaenoptera physalus*): 20 and 1,500-2,500 Hz; humpback whale (*Megaptera novaeangliae*): 25-360, 750-1,800, and 100-4,000 Hz; northern right whale (*Eubalaena glacialis*): 160-500 and 50-500 Hz; sei whale (*Balaenoptera borealis*): 3,000 Hz; and sperm whale (*Physeter macrocephalus*): 2,000-4,000 and 10,000-16,000 Hz] (Richardson et al., 1995; Advanced Research Projects Agency, 1995).

4.4 MITIGATION PHASES

The mitigation plan consists of three phases:

- <u>**Specific Test Site Selection Surveys**</u> — selecting a suitable test site, 5.6 km (3 nmi) in radius, which poses the least risk to the marine environment;

- <u>**Pre-Detonation Monitoring**</u> — effectively monitoring that site prior to each detonation in an effort to ensure that it is free of marine mammals, turtles, large schools of fish, and flocks of seabirds; and

- <u>**Post-Detonation Monitoring**</u> — determining the effectiveness of the mitigation efforts, by using a Marine Animal Recovery Team (MART) and aerial observers to monitor the test site and surrounding waters for injured or dead animals after each detonation.

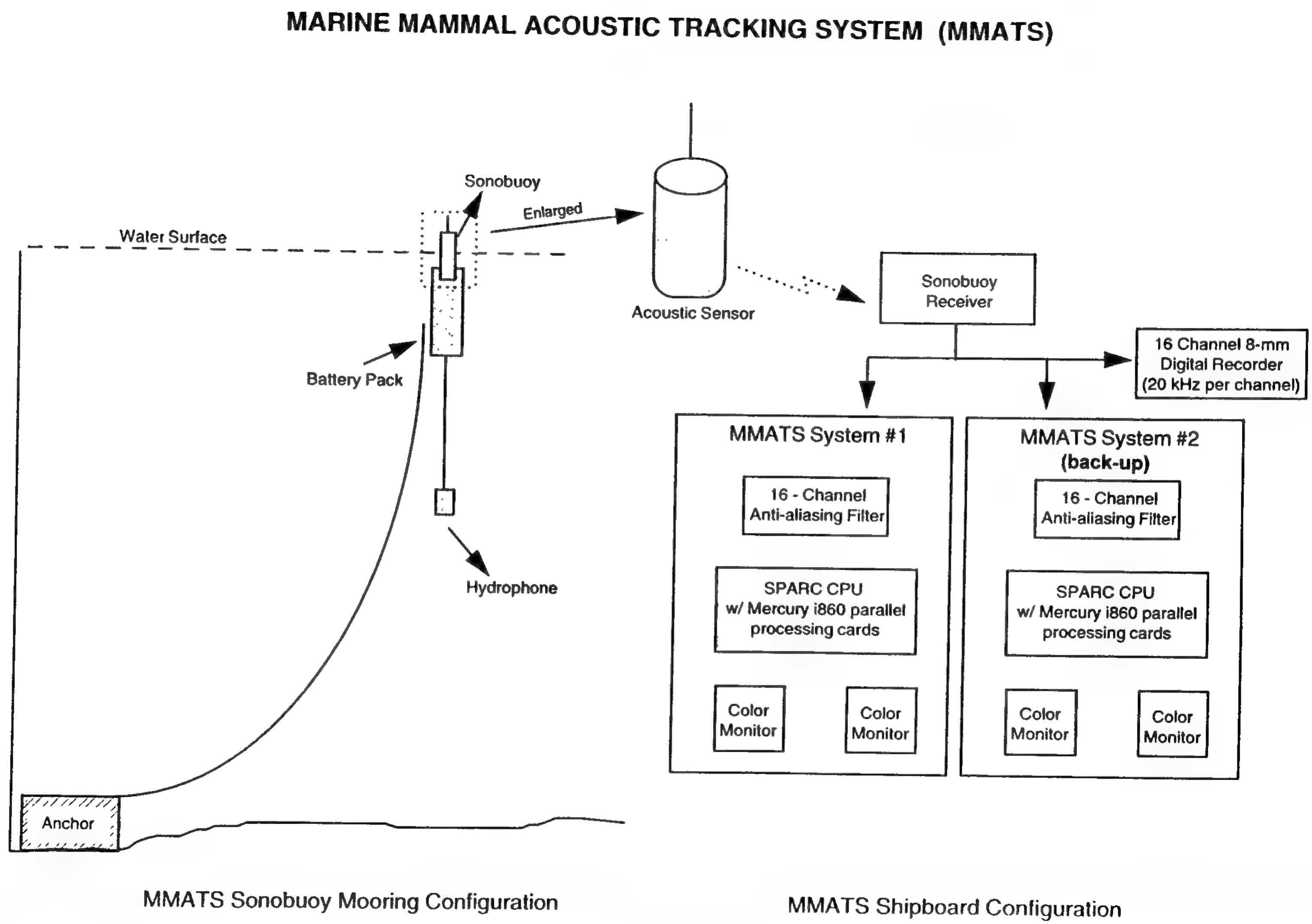


Figure 4-2. Marine Mammal Acoustic Tracking System (MMATS) sonobuoy mooring and shipboard configurations.

4.4.1 Test Site Selection Surveys

The purpose of the test site selection surveys is to select a site having the fewest marine mammals and turtles for the shock test. Two types of test site selection surveys would be conducted. First, aerial surveys three weeks prior to the first detonation would provide data for selection of a primary test site and two secondary test sites. Second, aerial surveys two to three days before each detonation would confirm one of these as the final test site.

Three Weeks Prior to Detonation

Three weeks prior to the shock test, a single aerial survey would be conducted over the selected area (i.e., Mayport or Norfolk) to identify potential test sites with the lowest density of marine mammals and turtles. The selected area would be surveyed by flying east-west transects centered on the 152 m (500 ft) depth contour and extending approximately 7.4 km (4 nmi) to either side (**Figures 4-3 and 4-4**). From the sightings data, a single primary test site and two secondary test sites would be selected based on lowest relative abundance of marine mammals and turtles. Abundance totals would be determined initially in groups of five transects (e.g., transects 1 through 5, 2 through 6, etc.), which encompasses an area slightly larger than a potential test site. Sliding abundance totals for each transect group would then be compared to determine lowest relative abundance; transect groupings may also be enlarged (e.g., groups of 10 and/or 15) to allow greater flexibility in determining those sites with the lowest relative abundance.

Two to Three Days Prior to Detonation

An aerial survey would be conducted approximately at the three sites two to three days prior to each detonation (i.e., 24 to 36 hr prior to setting the array) in order to rank the sites by scarcity of marine mammals (**Figure 4-5**). Through the comparison of data collected during this survey, the selection of the primary and two secondary test sites will be confirmed. The proposed detonation point would lie at the center of each survey area, which measures 14.8 km x 14.8 km (8 nmi by 8 nmi). Through the comparison of data collected during this survey, a final test site selection would be made by the OTC, the Test Director, and the Lead Scientist.

4.4.2 Pre-Detonation Monitoring

The purpose of pre-detonation monitoring is to ensure that marine mammals and turtles are absent from the selected test site at the time of detonation. Two and one-half hours before each detonation, aerial and shipboard observers would begin to visually search for marine mammals and turtles. Two hours prior to detonation, MMATS monitoring would be conducted to detect vocalizing marine mammals.

Shipboard monitoring from the operations and MART vessels would focus on a 5.6 km (3 nmi) radius from the detonation point (encompassing the safety range and buffer zone) to preclude physical injury or mortality to marine mammals and turtles. Binoculars (25x power) mounted on the flying bridge or bridge wings of the two vessels

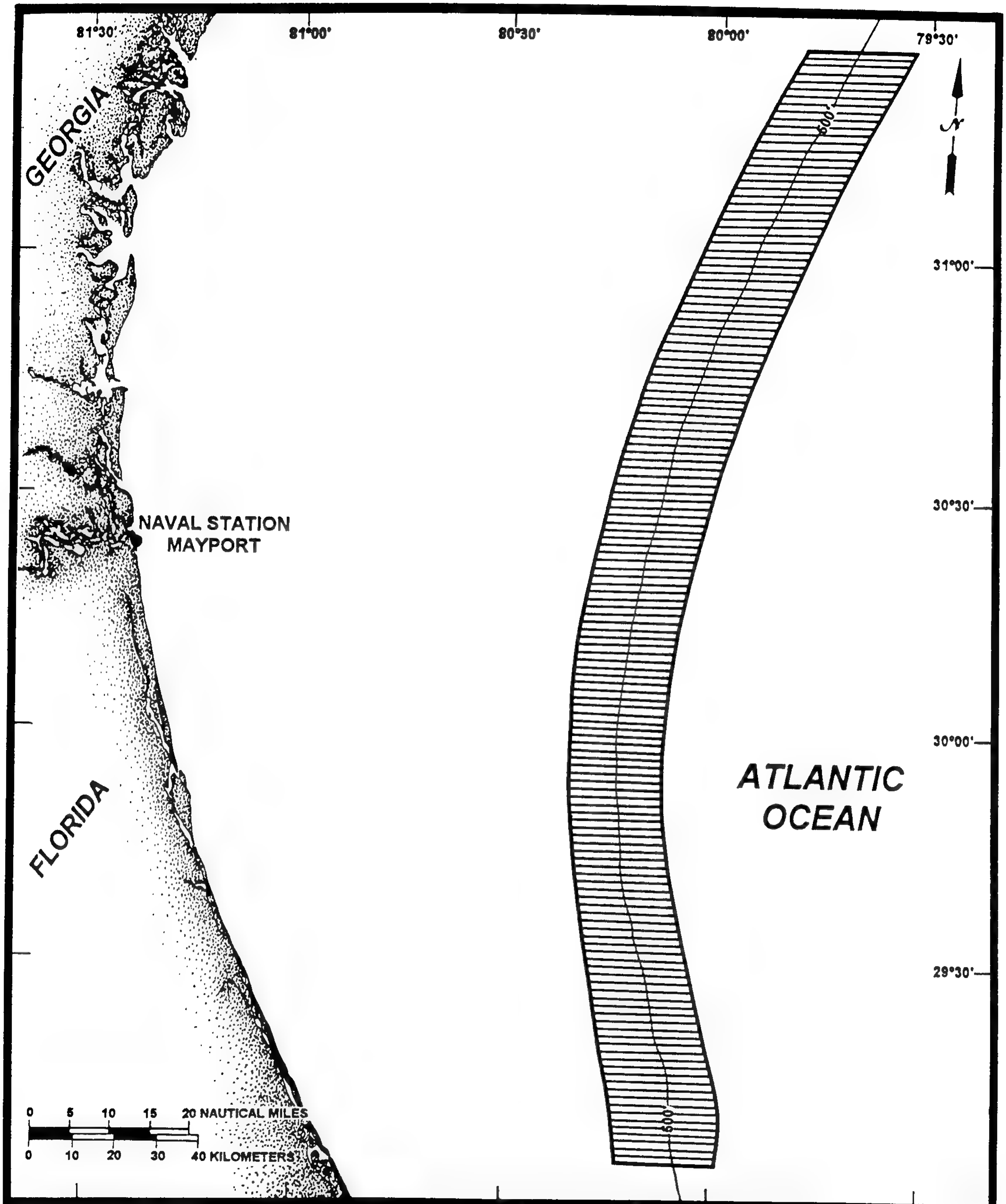


Figure 4-3. Location of aerial survey transects for test site selection three weeks prior to the shock test, if the Mayport area is selected.

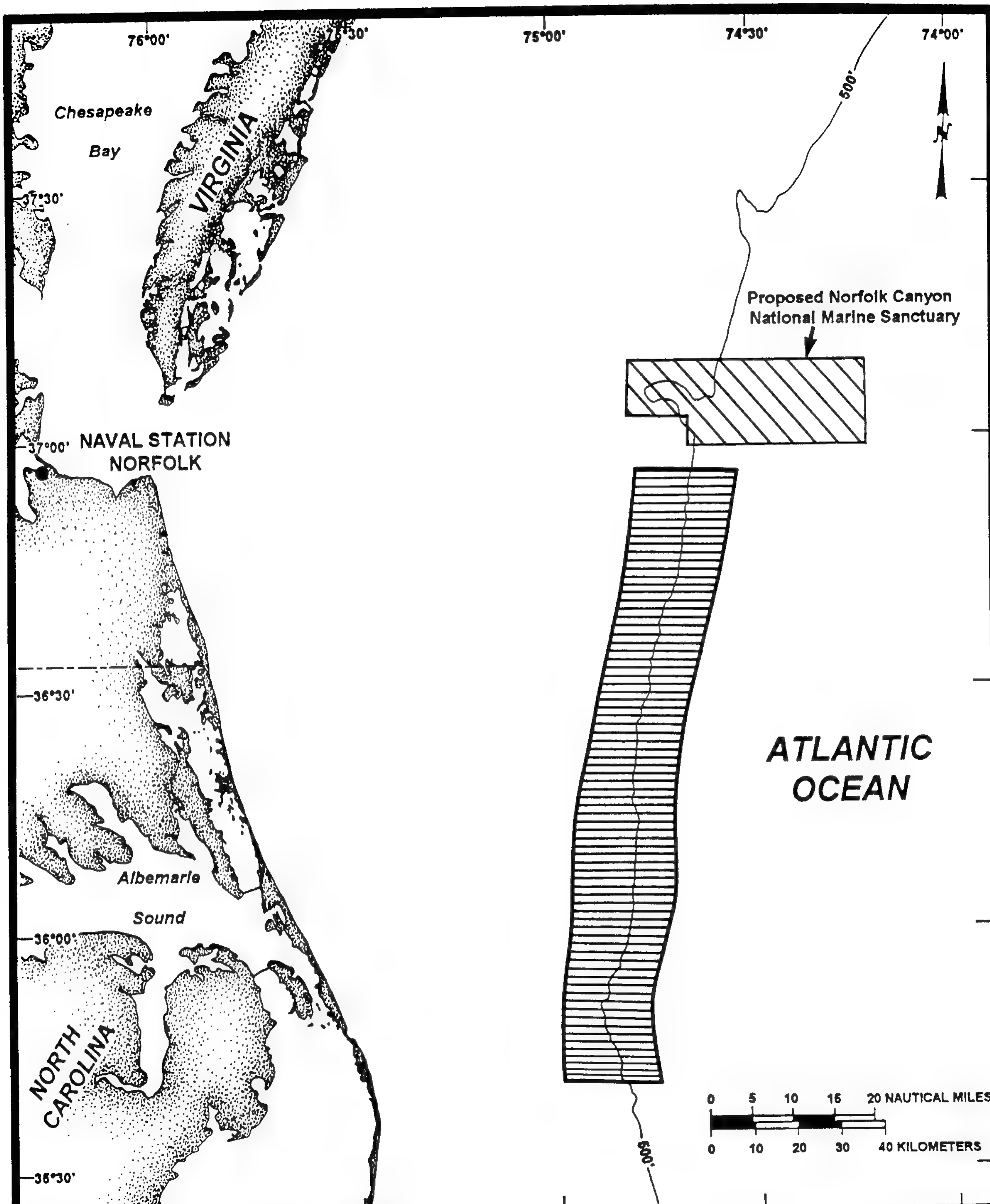


Figure 4-4. Location of aerial survey transects for test site selection three weeks prior to the shock test, if the Norfolk area is selected.

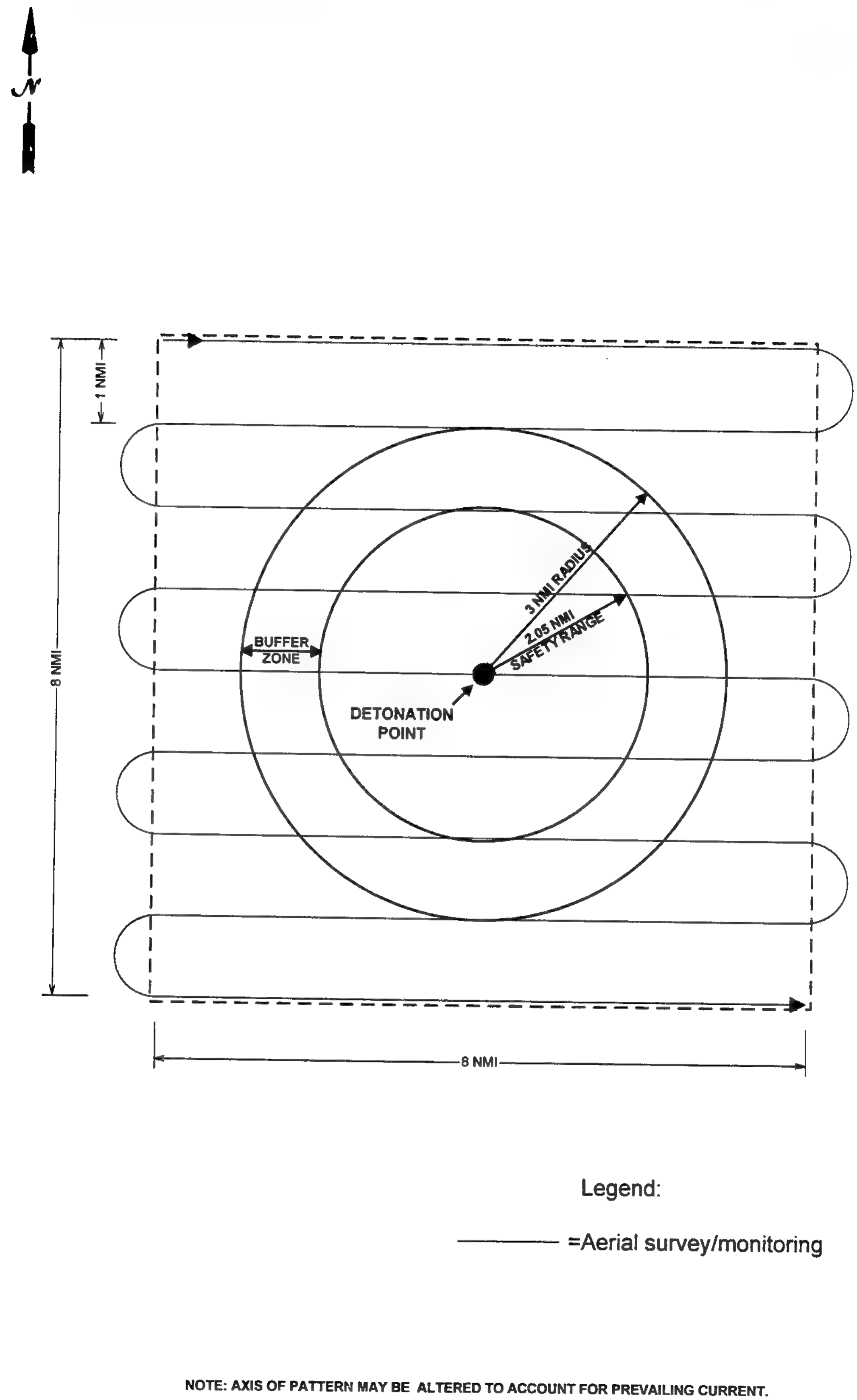


Figure 4-5. Flight plan two to three days and 2.5 hours prior to detonation.

would provide full 360° overlapping coverage. Other observers would use hand-held binoculars.

Shipboard monitoring from the MART vessel would be conducted by observers experienced in marine mammal observation. A veterinarian would coordinate the tagging and retrieval of any dead or injured animals discovered during aerial or shipboard pre-detonation monitoring. The MART responsibilities during pre-detonation monitoring are as follows:

- Deploy MMATS acoustic sensors;
- Conduct supplementary pre-detonation observations for marine mammals and turtles;
- Assist the aerial monitoring team in species identifications of selected individuals or groups; and
- Investigate large patches of *Sargassum* algae for the presence of juvenile sea turtles, and retrieve, as necessary.

Six Hours Prior to Detonation

Approximately six hours prior to detonation, the MART vessel would deploy 10 to 15 passive acoustic sensors (sonobuoys) throughout the test site; the total number of sensors to be deployed would depend upon ambient acoustic propagation and noise conditions in the vicinity of the detonation point. The sensors would be anchored to the bottom during the test, and would be retrieved afterwards. A representative pattern for sensor deployment, providing complete coverage of the test site, is illustrated in **Figure 4-6**. Deployment of the acoustic sensors in this pattern is intended to provide detection and localization of submerged marine mammals calls to a maximum distance of 14.8 km (8 nmi) from the detonation point for strong, low frequency calls common to whales and 3.9 km (2.1 nmi) for weak, high frequency calls common to dolphins.

Two and One-half Hours Prior to Detonation

Two and one-half hours prior to detonation, aerial monitoring would be conducted within the 14.8 km x 14.8 km (8 nmi x 8 nmi) monitoring area (see **Figure 4-5**). Shipboard observers on the operations and MART vessels would also monitor the test site from positions within a 5.6 km (3 nmi) radius of the detonation point. The MART vessel would deploy a Zodiac (or equivalent) to investigate large beds of *Sargassum* identified by the aerial team.

Two Hours Prior to Detonation

Two hours prior to detonation, the MMATS system would be calibrated. Two bioacousticians with extensive marine mammal vocalization (call) identification experience would monitor the system's receivers mounted onboard the operations vessel. Depending upon ambient oceanographic conditions, the MMATS team should have the ability to locate any vocalizing animals which may be approaching the test site. All noise signals would be interpreted, identified by species, and located. This information would be relayed to the Lead Scientist who would record the animal's location relative to the test site.

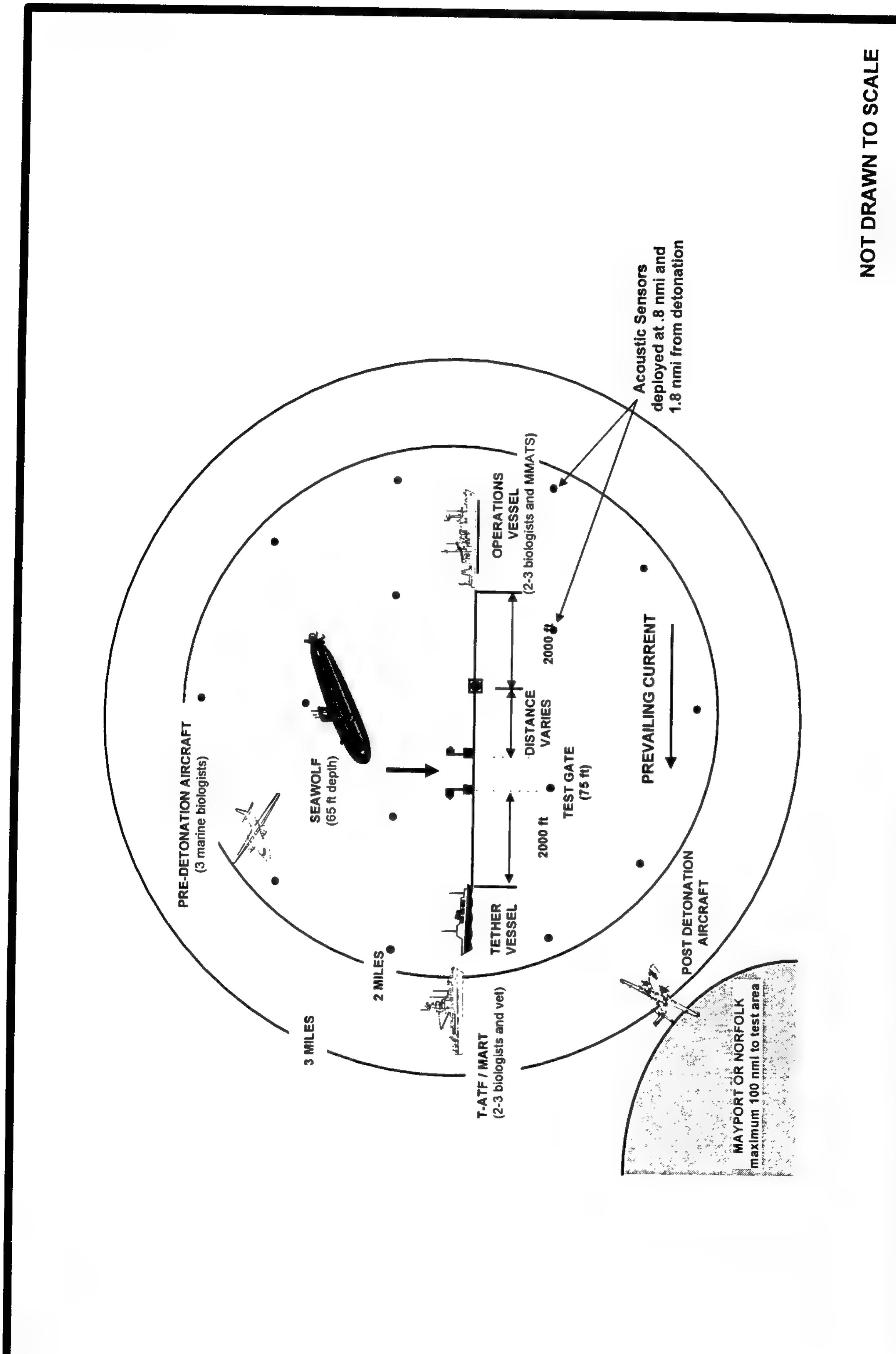


Figure 4-6. Sonobuoy deployment pattern relative to the three mile radius and the positions of the operations and MART vessels and detonation point.

One Hour Prior to Detonation

One hour prior to detonation, monitoring of the area within a 5.6 km (3 nmi) radius of the detonation point would be performed (**Figure 4-7**) using a single aircraft, the MART vessel, and the operations vessel, enabling complete coverage of the test site prior to detonation. Aboard the aircraft, observers would follow a line transect pattern, followed by overflight of the detonation point and a series of three concentric circles outward from the detonation point. The axis of the pattern may be altered to account for prevailing currents in the vicinity of the test site.

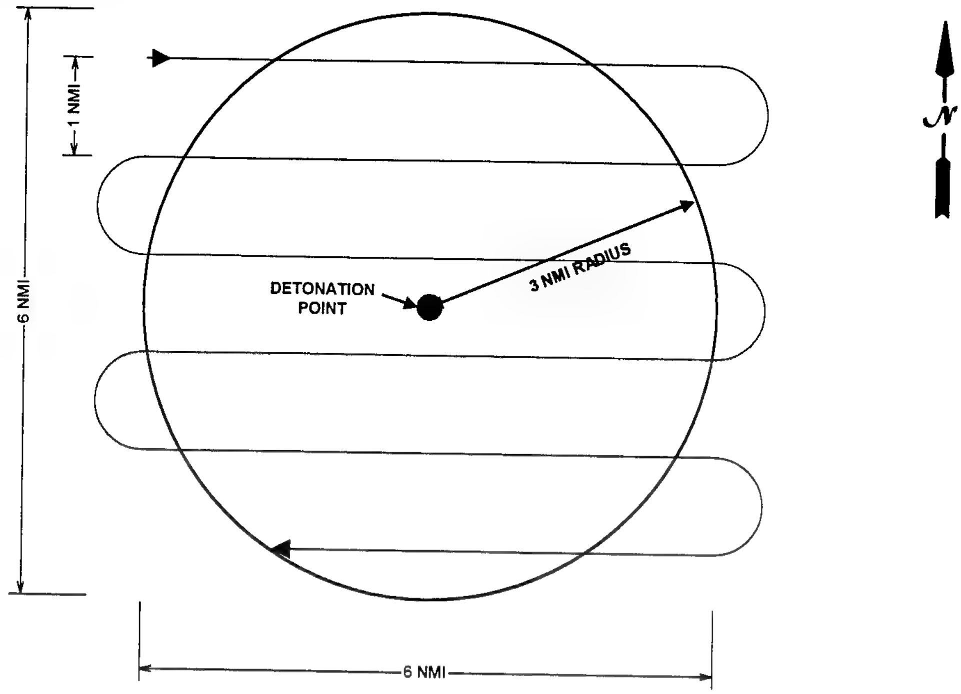
As reflected in **Figure 4-7(a)**, the initial phase of monitoring would consist of the line transect pattern, where a total of six east-west transects would be completed at 1.85 km (1 nmi) intervals. Following completion of the bottom east-west transect, the aircraft would follow the 5.6 km (3 nmi) radius to a point almost directly west of the detonation point. The aircraft would then turn east towards the detonation point. After crossing the detonation point, the aircraft would continue east to the 0.9 km (0.5 nmi) radius, turn northward, and complete the radius in a counter-clockwise direction. Once the 0.9 km (0.5 nmi) radius is completed, the aircraft would move to the 2.8 and 4.6 km (1.5 and 2.5 nmi) radii to complete each concentric circle in similar fashion. Once the final concentric circle is completed along the 4.6 km (2.5 nmi) radius, the aircraft would maintain this distance until after detonation. **Figure 4-6** illustrates the general position of all operational and mitigation assets during the pre-detonation period.

Flight lines [i.e., transects and concentric circles shown in **Figure 4-7(a)** and **4-7(b)**] are designed to search for marine mammals and turtles which may be present within 5.6 km (3 nmi) of the detonation point or that may swim into the safety range immediately prior to the detonation. While the initial east-west flight transects are intended to ensure that no marine mammals or sea turtles are present within the safety range, the overflight along the concentric circles is designed to further ensure that no mammals or turtles have entered the safety range during completion of the line transects. At a flight speed of 110 kt, completion of six line transects and five turns would require a total of less than 30 minutes (i.e., 3.3 min/transect; 1.7 min/turn). Completion of the concentric circles would require an additional 21 minutes. As noted previously, the aircraft would complete the 4.6 km (2.5 nmi) radius as the last of the concentric circles, holding that distance from the detonation point until detonation. This would assure effective monitoring of the buffer zone by the aerial team immediately prior to detonation. A summary of the distances and estimated travel times for each aerial monitoring component is provided in **Table 4-1**.

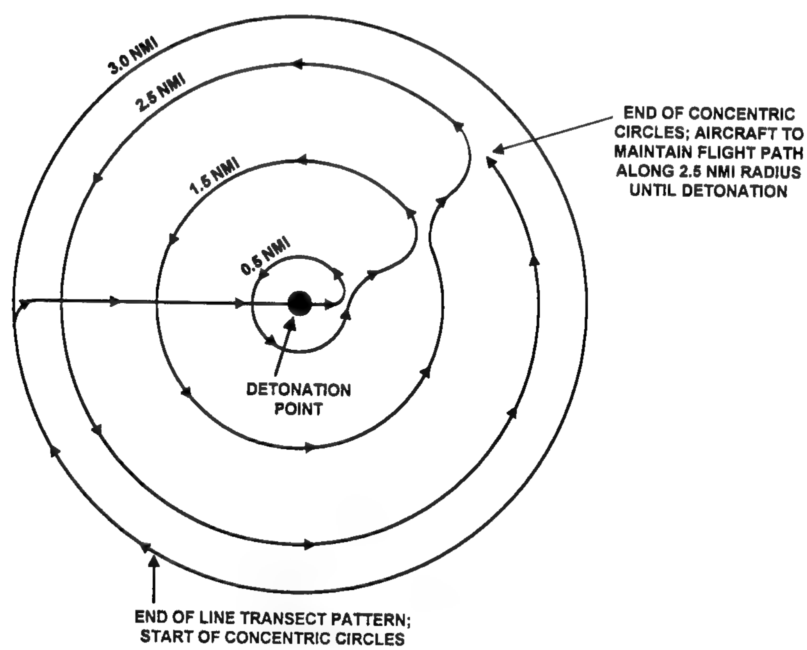
To account for marine mammals or sea turtles that may enter into the buffer zone and move towards the safety range during the period of time the aircraft is flying its transects, shipboard observers and the MMATS team would monitor the 5.6 km (3 nmi) (radius) test site. Shipboard observers would place emphasis on those portions of the test site that the aircraft has already monitored, while MMATS personnel would continue to monitor the entire test site.

Immediately prior to detonation and upon request of the OTC, the MART vessel would stand by at a distance of 3.7 km (2 nmi) from the detonation point. Detonation would not occur if: (1) any marine mammals or sea turtles were *visually*

(a)



(b)



Legend:

―――― =Aerial monitoring

Figure 4-7. Flight plan 1.0 hour prior to detonation.

Table 4-1. Distances and time required for completion of the aerial monitoring one hour prior to detonation.

Survey Component	Distance		Time Required (min)
	nmi	km	
Line Transects			
6 transects	36.0	66.6	19.8
5 turns	15.7	29.1	8.6
Total line transects	51.7	95.7	28.4
Concentric Circles			
To 0.5 nmi circle	6.0	11.1	3.3
0.5 nmi circle	3.14	5.81	1.7
From 0.5 nmi circle to 1.5 nmi circle	1.5	2.78	0.9
1.5 nmi circle	9.4	17.41	5.2
From 1.5 nmi circle to 2.5 nmi circle	1.5	2.78	0.8
2.5 nmi circle	15.7	29.1	8.6
Total concentric circles	37.24	68.98	20.5
TOTAL	**88.94 nmi**	**164.68 km**	**48.9 min**

detected within 3.8 km (2.05 nmi) of the detonation point; (2) any marine mammals were *acoustically* detected within 4.3 km (2.3 nmi) of the detonation point (it would be assumed that the animal is within the 3.8 km (2.05 nmi) safety range); and (3) flocks of seabirds or large schools of fish were observed in the water within 1.85 km (1 nmi) of the detonation point.

4.4.3 Post-Detonation Monitoring

Post-detonation monitoring would be conducted by the MART vessel for a period of 48 hours after each detonation. The MART vessel would be assisted by the aerial mitigation team for up to three hours per day during the same 48 hours. Aerial and shipboard monitoring are intended to locate and identify any dead or injured animals. The MART would document any marine mammals or turtles that were killed or injured as a result of the shock test and, if practicable, recover and examine any dead animals. The behavior of any animals observed by MART and the aerial team would be documented.

Immediately Following Detonation

The aerial team would monitor the area of the test [5.6 km (3 nmi) radius] immediately following the detonation (**Figure 4-8**) and report any sightings of dead or injured marine mammals or turtles to the MART. After completing this initial monitoring of the test site, the aerial team would monitor an 11.1 km (6 nmi) radius area from the detonation point, starting at the southern end and continuing north- or northeast-ward. Aerial monitoring, with transects spaced 1.85 km (1 nmi) apart, would continue northward for three hours after the detonation, or until sighting conditions are unsuitable (e.g., due to nightfall).

The MART vessel would move to the detonation point immediately following the detonation to search for dead fish or turtles, and then proceed to the top boundary of the 5.6 km (3 nmi) radius to search for any animals which have drifted with the current. Once at this position, the MART vessel would commence an 11.1 km (6 nmi) long racetrack pattern, centered 5.6 km (3 nmi) north of the detonation point (**Figure 4-8**) for one hour, intercepting any dead or injured marine animals drifting with the current. After one hour, the MART vessel would reposition an additional 3.7 km (2 nmi) north (or northeast, depending on prevailing current) of the detonation point and commence the same racetrack pattern for another hour. The MART vessel would continue to reposition in this manner until nightfall. MART would immediately break away from the racetrack pattern to investigate any sightings of potentially injured or dead marine animals reported by the aerial monitoring team.

Post-Detonation Days 1 and 2

Monitoring by the aerial team and MART would continue on post-detonation days 1 and 2 to detect any potentially injured or dead animals moving in the predominant direction and speed of the Gulf Stream (**Figure 4-9**). Drogues or lighted buoys deployed by the MART vessel would determine current attributes. Satellite imagery may also be used to further refine current speed and direction estimates. The aerial team would monitor for at least three hours each day along transects 22.2 km (12 nmi) in length

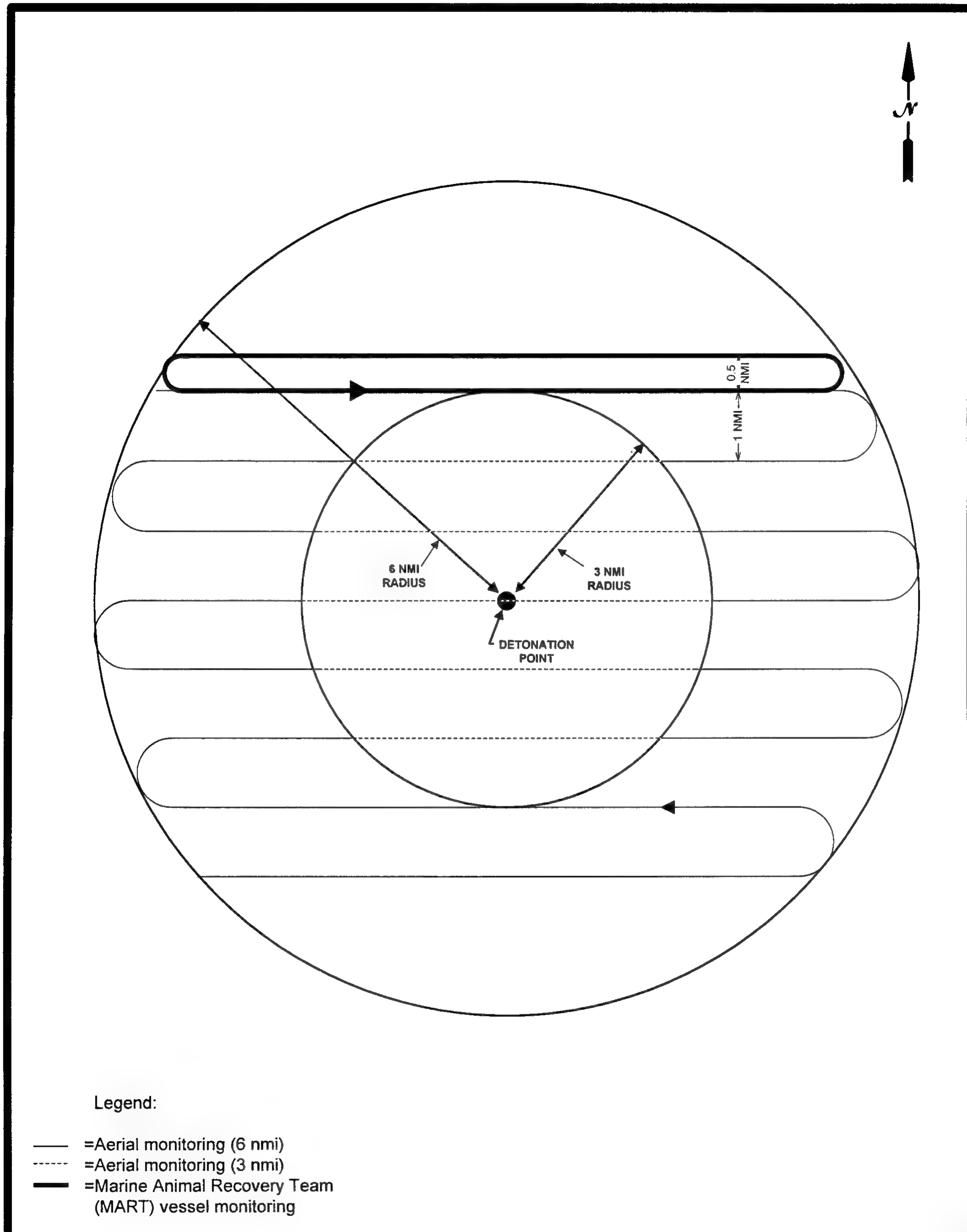


Figure 4-8. Flight and MART vessel plan immediately following detonation.

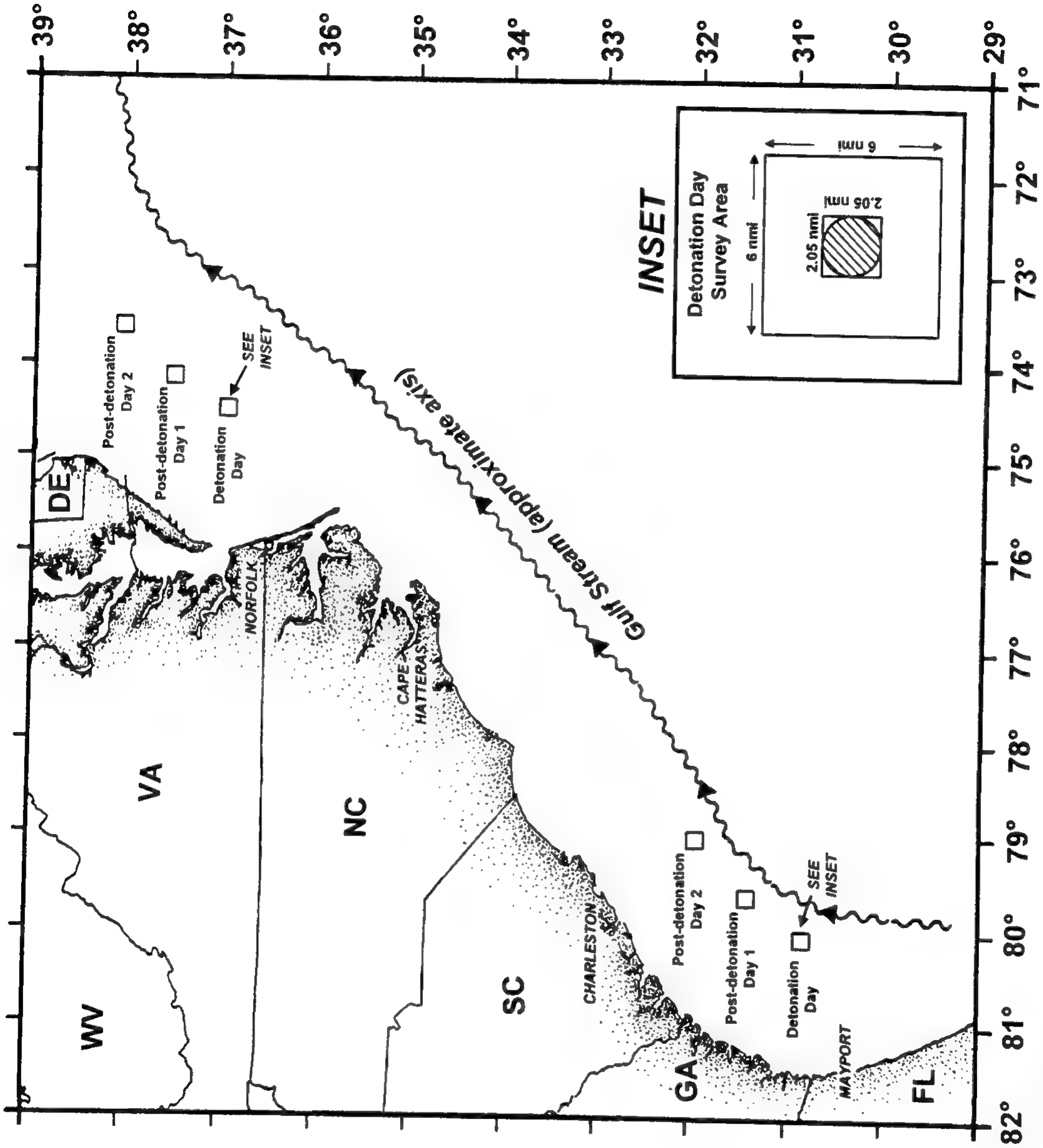


Figure 4-9. Projected location of post-detonation monitoring immediately following detonation and on post-detonation days 1 and 2.

spaced 1.85 km (1 nmi) apart. Aerial transects would correspond to the position of the MART vessel and move progressively north- or northeastward.

As its first task on post-detonation days 1 and 2, the aerial team supporting the MART would return to the detonation point to observe and document the behavior of any animals in the area, after which they would move downcurrent to continue their observations. The MART vessel would continue the 11.1 km (6 nmi) long racetrack pattern throughout the day, moving 3.7 km (2 nmi) northeast each hour. MART would immediately break away from the racetrack pattern to investigate any sightings of potentially injured or dead marine animals reported by the aerial monitoring team. At the end of post-detonation day 1, MART would deploy another drogue or lighted buoy to determine current direction and speed. The area to be monitored on post-detonation day 2 would be determined based on the results of the drift (**Figure 4-9**).

In total, the MART team would continuously monitor the area around the detonation site and areas downcurrent for at least 24 of the 48 hours following each detonation, covering approximately 444 km (240 nmi), based on two post-detonation monitoring days and an average vessel speed of 10 kt. The aerial team is expected to monitor as much as 1,833 km (990 nmi) during the same 48 hour period, based on a maximum of nine hours on station (i.e., three hours immediately after detonation, three hours each on post-detonation days 1 and 2) and an average flight velocity of 110 kt. If the post-detonation monitoring determines that injurious or lethal takes have occurred, a review and change of test procedures and monitoring methods would be made as necessary. A flow chart depicting the pre- and post-detonation MART action plan is shown in **Figure 4-10**.

Communications With Marine Animal Stranding Network(s)

The NMFS maintains regional stranding networks along the northeast (Maine to Virginia) and southeast (North Carolina to Texas, Puerto Rico, and the U.S. Virgin Islands) coasts to coordinate collection and dissemination of information about marine mammal strandings. The Lead Scientist would contact the designated coordinator of the appropriate stranding network after each detonation and report any observations of injured or killed marine mammals or turtles that cannot be recovered by the MART. Communications with stranding network personnel would be maintained throughout the SEAWOLF shock test period and any marine animal found stranded up to one month after the last test would undergo full necropsy to determine, as possible, cause of death.

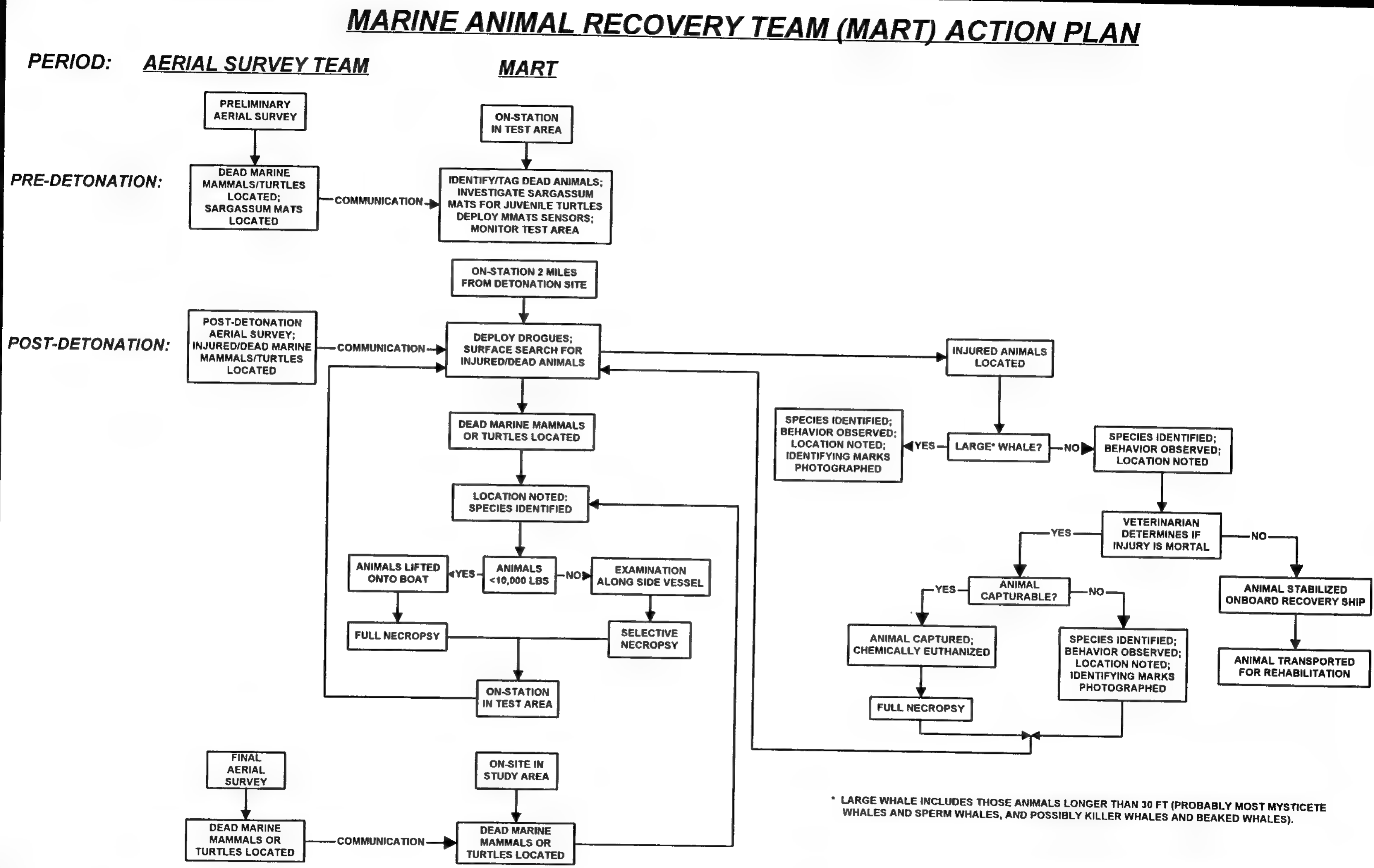


Figure 4-10. Flow chart depicting MART action plan during pre- and post-detonation periods.

5.0 ALTERNATIVES

The DEIS (Department of the Navy, 1996) evaluates a "no action" alternative and alternative areas for the proposed shock testing. Alternative offshore areas for shock testing are compared from operational and environmental perspectives. A preferred alternative is selected based on these comparisons. A synopsis of the alternatives analysis is presented here.

5.1 NO ACTION

Under the "no action" alternative, no new activities affecting the physical environment would be conducted to predict the response of SEAWOLF class submarines to underwater detonations. This alternative would by definition avoid all environmental impacts of shock testing.

As described in the DEIS, the Navy has established a Live Fire Test and Evaluation (LFT&E) program to complete the survivability testing of the SEAWOLF class submarines. The program consists of three major areas which together provide the data necessary to assess the SEAWOLF's survivability: computer modeling and analysis, component and surrogate testing, and a shock test of the entire ship. The SEAWOLF LFT&E program already includes the maximum reasonable amount of computer modeling and component testing. Only by testing the entire ship manned with the appropriate systems operating can the shock response of the entire ship, including the interaction of ship systems and components, be obtained and an adequate assessment of the survivability of the submarine be determined in accordance with 10 USC 2366. The intent of 10 USC 2366 is to ensure that the combat survivability of the weapon system (submarine) is assessed before the system is exposed to hostile fire. The information obtained during the shock test is used to improve the shock resistance of the ship and therefore reduce the risk of injury to the crew. The "no action" alternative would prevent the Navy from being able to make the survivability assessment required by 10 USC 2366.

As the "no action" alternative involves no activity affecting the physical environment, it is not individually analyzed further in the DEIS. The "no action" alternative is implicit in the environmental analysis throughout the document. The Existing Environment section of the DEIS provides a "no action" benchmark against which the proposed action can be evaluated. The Environmental Consequences of the DEIS section compares impacts of an action (shock testing) with the alternative of "no action."

5.2 ALTERNATIVE AREAS FOR THE PROPOSED ACTION

The remaining alternative discussed is the proposed action, which is to shock test the SEAWOLF at an offshore location. Several possible general areas for shock testing were evaluated by the Navy, as described below. The final, specific site for shock testing would not be selected until 2 to 3 days before the test based on marine mammal and turtle surveys (see Section 4.0). However, the Navy has identified general offshore areas which meet certain operational criteria, and has a preferred area. The final test site would be selected within the preferred area if this alternative is selected.

5.2.1 Operational Requirements

5.2.1.1 Scheduling and PERSTEMPO Requirements

A location on the east coast would best meet operational needs because that is where the SEAWOLF will be homeported and where all sea trials will occur. Scheduling the test on the west coast or in the Gulf of Mexico would increase the time the ship is away from the homeport, complicate or prolong repairs, and further delay deployment. Under Navy Personnel Tempo (PERSTEMPO) regulations, a ship is required to spend a day in homeport for every day it is away from homeport for purposes of crew quality of life and efficiency (OPNAVINST 3000.13A, 21 December 1990). A shock test conducted away from the homeport is typically a 3½ to 4 month deployment, including time spent having special equipment installed at the shore support facility, completing test runs and training, and conducting the actual shock testing. Scheduling the test away from the east coast would maximize time spent away from the homeport and minimize the SEAWOLF's availability for deployment as part of fleet resources.

The Navy screened possible east coast shock testing areas according to operational criteria. Potential areas were first defined as locations having a water depth of 152 m (500 ft) that are within 185 km (100 nmi) of a naval station support facility and a submarine repair facility. This water depth is sufficient to minimize the effect of a bottom reflected pressure wave on the submarine and shallow enough to allow mooring of the operations vessel with the test array. This depth would also permit recovery of the crew and submarine in the unlikely event of a control failure. Other criteria include proximity to an ordnance storage/loading facility and Navy assets (ships and aircraft) necessary to support the test needs. There must also be little or no shipping traffic in the area. Finally, calm seas and good visibility are needed for the test, so a location that has a preponderance of such is needed. The rationale for each of these operational requirements is explained in separate subsections below.

Five east coast areas were identified that could potentially meet the Navy's operational requirements: Mayport, Florida; Norfolk, Virginia; Groton, Connecticut; Charleston, South Carolina; and Key West, Florida. Charleston was eliminated because of the closure of the Charleston Navy Yard and Charleston Naval Station under the Base Closure and Realignment (BRAC) process (i.e., facilities and vessels to support the test would not be available). The water depth of 275 m (900 ft) at the Key West area is too great for the planned shock testing. In addition, the Key West area lacks the industrial base to support submarine repairs or drydocking, and there is no surface vessel homeport nearby which could provide Navy assets (ships and planes) to support the test.

The following sections evaluate the remaining three areas (Mayport, Norfolk, and Groton) according to the Navy's operational criteria. A summary and comparison is presented after the individual criteria have been discussed.

5.2.1.2 Proximity to Naval Station Support Facility

A Naval Station which can provide limited maintenance and depot level support for submarines (e.g., tradespeople, spare parts, cranes) must be located near the test site to repair/replace damaged equipment and systems. A reasonable distance is 185 km

(100 nmi), which would allow a 20- to 24-hr transit time for the SEAWOLF (assuming the submarine is surfaced and traveling at a speed of about 4 to 5 kt).

All three remaining areas are within 185 km (100 nmi) of a shock test support facility. For the Mayport area, the support facility would be the Kings Bay Naval Submarine Base, with distances ranging from to 139 to 185 km (75 to 100 nmi). For the Norfolk area, the support facility would be Naval Station Norfolk, with distances ranging from 148 to 185 km (80 to 100 nmi). For the Groton area, the support facility would be New London Submarine Base, with distances ranging from 167 to 185 km (90 to 100 nmi).

5.2.1.3 Proximity to Submarine Repair Facility

Close proximity to a submarine repair facility is imperative for the SEAWOLF shock test. A repair facility must be nearby to provide drydocking, special trades, equipment, and materials to perform post-test inspections and prepare for the next test. A reasonable distance between the repair facility and the test site is 185 km (100 nmi), which would allow a 20- to 24-hr transit time for the SEAWOLF (assuming the submarine is surfaced and traveling at a speed of about 4 to 5 kt).

If testing occurred offshore of Mayport, then the Kings Bay Naval Submarine Base would serve as the repair facility. Distances to the repair facility range from 139 to 185 km (75 to 100 nmi). If testing occurred offshore of Norfolk, then the Norfolk Naval Shipyard would serve as the repair facility; distances to the repair facility range from about 148 to 185 km (80 to 100 nmi). If Groton were selected, the shipbuilder's yard in Groton could be used for repairs. Distances range from about 167 to 185 km (90 to 100 nmi).

5.2.1.4 Proximity to Ordnance Storage/Loading Facility

Prior to each test, an explosive would be loaded onto the operations vessel at an ordnance storage/loading facility. The facility must have qualified personnel and equipment to handle the explosives and must be located within about 370 km (200 nmi), which allows a 20- to 24-hr transit at 8 to 10 kt. Greater distances could increase the time to prepare for the next test and preclude windows of opportunity to test on weather-favorable days.

All three areas are within 370 km (200 nmi) of ordnance storage/loading facilities. If the Mayport area is selected, then explosives would be stored and loaded either at the Naval Weapons Station in Charleston, South Carolina, a distance of 185 to 370 km (100 to 200 nmi); or at Naval Station Mayport, a distance of 117 to 185 km (63 to 100 nmi). For testing offshore of Norfolk, explosives would be stored and loaded at the Naval Weapons Station in Yorktown, Virginia, a distance of about 185 to 222 km (100 to 120 nmi). If Groton were selected, then the explosives would be stored and loaded at the Naval Weapons Station in Earle, New Jersey, about 195 to 287 km (105 to 155 nmi) away.

5.2.1.5 Availability of Navy Assets

Navy ships would be needed at the test site to monitor, divert, and escort non-test vessels away from the exclusion zone, provide communications, track the SEAWOLF, and perform other tasks. Airplanes and helicopters would serve as observation and photographic platforms before, during, and after the test and would also be available for emergency response and rescue. For sufficient vessels and aircraft (and alternates) to be available, a large Navy installation must be within 185 km (100 nmi) of the test site. This would allow a 8- to 10-hr transit time for support craft steaming at 10 to 12 kt. The distance would also allow each support aircraft to remain on-site for about 3 to 3½ hr, with an adequate fuel reserve for safety.

The availability of Navy assets is an important consideration given the need for a variety of Navy vessels and aircraft for shock test support. In recent years, obtaining Navy assets (both air and surface) has become increasingly difficult as both the budget and the size of the Navy have decreased. Supporting a shock test reduces fleet assets available to meet the other mission goals of the Atlantic Fleet. Therefore, to minimize transit times and make the most effective use of Navy assets, it is imperative that the SEAWOLF shock testing be conducted at a location which is close to a large Navy installation with available ships and aircraft to support the test.

Because large Navy installations are located at Mayport, Florida, and Norfolk, Virginia, the Navy is in the best position to support shock testing at these two areas. Transit distances range from 117 to 185 km (63 to 100 nmi) for sites in the Mayport area and 148 to 185 km (80 to 100 nmi) for sites in the Norfolk area. Shock testing at Groton would be very difficult because there are no nearby Navy installations with the fleet operational assets required to support shock testing. The nearest Navy installations at Newport, Rhode Island and Staten Island, New York are now closed. Naval Station Philadelphia is also closed. Earle Naval Weapons Station in Colts Neck, New Jersey is homeport to only a few ships, none of which are of the type needed to support shock testing. Therefore, the nearest Naval Station which would have available assets to support shock testing in the Groton area is Naval Station Norfolk, with distances ranging from 474 to 585 km (256 to 316 nmi).

5.2.1.6 Proximity to SEAWOLF Homeport

Proximity to New London, Connecticut is desirable because it is the proposed homeport for the SEAWOLF (Department of the Navy, 1995b). The Groton area is obviously closest to the SEAWOLF homeport, about 167 to 185 km (90 to 100 nmi). New London is about 1,250 to 1,482 km (675 to 800 nmi) from the Mayport area and about 555 to 675 km (300 to 365 nmi) from the Norfolk area.

5.2.1.7 Water Depth

A water depth of 152 m (500 ft) is sufficient to minimize the effect of a bottom reflected pressure wave on the submarine and shallow enough to allow mooring of the operations vessel with the test array. This depth would permit recovery of the crew and submarine in the unlikely event of a control failure.

All three areas satisfy the water depth requirement. That is, the areas were initially defined as all points along the 152 m (500 ft) depth contour within 185 km (100 nmi) of the shock test support facility.

5.2.1.8 *Ship Traffic*

An area with little or no ship traffic is preferred; established shipping and submarine transit lanes should be avoided. Ships passing near the shock test site would not be in any danger, but their presence could delay shock testing. An exclusion zone of 9.3 km (5 nmi) radius would be established around the test site to exclude all non-test ship, submarine, and aircraft traffic. Notices to Airmen and Mariners would be published in advance of each test. Any traffic entering an 18.5 km (10 nmi) radius around the detonation point would be warned to alter course or would be escorted from the site. Testing could be delayed while support vessels divert and escort the traffic away from the test site.

Any of the three areas would be acceptable from the standpoint of ship traffic. None are located in or near shipping lanes or submarine transit lanes. However, data from port authorities for ports near each location indicate that the Mayport area has about half as much commercial ship traffic as either the Norfolk or Groton areas (**Table 5-1**). The Groton area has the lowest density of military traffic, and the Norfolk area has the highest. Overall, the Mayport area is the most favorable and the Norfolk area is least favorable.

5.2.1.9 *Weather and Sea State*

Safe deployment, maintenance, and recovery of the test array, as well as effective mitigation, require good weather and sea conditions. Personnel on the operations vessel need a stable work platform while handling equipment and materials. Divers need calm seas to connect and reconnect the submarine "gate." Ideal test conditions are seas of 0.6 m (2 ft) or less, a light wind, and unlimited visibility. Conditions

Table 5-1. **Ship traffic levels near the Mayport, Norfolk, and Groton areas**. Sources: Georgia Port Authority, Hampton Roads Maritime Association, Jacksonville Port Authority, and Maritime Association of New York. Mayport ship traffic includes 50% of the traffic destined for Savannah, Georgia.

Type of Ship Traffic	Mayport	Norfolk	Groton
Commercial Ship Traffic			
Ships per year	2,400	5,300	4,750
Ships per day	7	15	13
Military Ship Traffic Density	Moderate	High	Low

become marginal when seas approach 1.8 m (6 ft), winds approach 34 kph (21 mph), and visibility is less than 9.3 km (5 nmi). In addition, a sea state of Beaufort 4 or less is required for visual observations of marine mammals and sea turtles during the pre-detonation monitoring (see Section 4.0).

Data from the Naval Oceanography Command (Department of the Navy, 1989) were used to evaluate the potential areas (**Table 5-2**). The data were available for three time intervals: March through May, June through August, and September through November. These intervals include the range of possible dates for the planned shock testing (1 April through 30 September).

Generally, the Mayport area has the highest probability of favorable conditions for most weather and sea state categories and time intervals. Conditions at the other two areas are similar with the exception of fog and visibility. Groton has a high incidence of fog (up to 26.6%) and low visibility during summer months, posing a significant operational safety risk which would result in testing delays.

5.2.1.10 Conclusions

Table 5-3 compares Mayport, Norfolk, and Groton according to the operational criteria. For each criterion (except for ship traffic and proximity to SEAWOLF homeport, which use ranks), the areas are scored on a scale of 0 to 4. Mayport and Norfolk have nearly identical totals (36 and 34, respectively), whereas Groton scores substantially lower (24). Groton scored poorly on criteria for incidence of fog and proximity to Navy assets (air and surface). The high incidence of fog and low visibility at Groton during summer months could result in frequent testing delays, reduce the effectiveness of mitigation measures, and pose safety problems for support vessels and aircraft. The lack of nearby Navy assets to support shock testing also makes this an unfavorable location from an operational perspective.

In summary, the above analysis shows that only the Mayport and Norfolk areas meet all of the Navy's operational requirements and that these two areas are rated as nearly equal. Therefore, only the Mayport and Norfolk areas are included in the detailed environmental analysis in this request for Letter of Authorization for the incidental take of marine mammals.

5.2.2 Environmental Considerations

At both the Mayport and Norfolk areas, possible test sites were defined to meet operational depth restrictions; this being any point along the 152 m (500 ft) depth contour within 185 km (100 nmi) of a naval station support facility and a submarine repair facility. Environmental features near each area were mapped, including marine sanctuaries, artificial reefs, hard bottom areas, shipwrecks, ocean disposal sites, and critical habitat for endangered or threatened species. Buffer zones were developed to avoid impacts to these areas and associated biota. Portions of the 152 m (500 ft) depth contour were excluded as summarized below.

At the Mayport area, there are no marine sanctuaries, artificial reefs, hard bottom areas, shipwrecks, ocean disposal sites, or critical habitat areas. Therefore, all

Table 5-2. Comparison of weather and sea state conditions at the Mayport, Norfolk, and Groton areas (Data from: Department of the Navy, 1989). The location having the most favorable percentage for each condition during each time period is shaded. Values that could result in frequent delays to shock testing are boxed with a thick line.

Weather/Sea State Condition	Percent Occurrence of Weather/Sea State Condition								
	Mar-May			Jun-Aug			Sep-Nov		
	Mayport	Norfolk	Groton	Mayport	Norfolk	Groton	Mayport	Norfolk	Groton
Ideal Conditions									
Seas ≤0.6 m (≤2 ft)	41.1	18.0	17.3	54.2	41.9	48.0	33.6	29.9	29.2
Visibility ≥18 km (≥10 nmi)	62.6	69.0	60.6	64.8	52.8	40.9	54.2	41.9	59.1
Marginal Conditions									
Seas ≤1.8 m (≤6 ft)	87.1	63.7	57.3	93.0	88.4	91.2	78.7	76.1	74.4
Wind ≤34 kph (≤21 mph)	94.7	85.3	78.7	95.7	96.0	97.1	82.6	83.1	86.4
Visibility ≥9.3 km (≥5 nmi)	97.2	94.8	90.8	96.8	90.1	76.2	97.9	94.3	91.8
Fog	0.4	8.0	15.0	0.1	3.5	26.6	0.2	2.3	7.9

Table 5-3. Evaluation of Mayport, Norfolk, and Groton areas according to operational criteria.

Criterion	Basis for Scoring	Scoring of Alternative Areas			Comments
		Mayport	Norfolk	Groton	
Facilities and Assets					
Shock test shore support facility within 185 km (100 nmi)	Portion of area meeting criterion: 0 = 0% 1 = 1-49% 2 = 50-74% 3 = 75-99% 4 = 100%	4	4	4	All areas are within 185 km (100 nmi) of a shock test support facility.
Submarine repair facility within 185 km (100 nmi)	(same as above)	4	4	4	All areas are within 185 km (100 nmi) of a submarine repair facility.
Ordnance storage/ loading facility within 370 km (200 nmi)	(same as above)	4	4	4	
Naval assets (surface) within 185 km (100 nmi)	(same as above)	4	4	0	Sources within 185 km (100 nmi) of Groton area are on base closure list.
Naval assets (air) within 185 km (100 nmi)	(same as above)	4	4	0	Sources within 185 km (100 nmi) of Groton area are on base closure list.
Proximity to SEAWOLF homeport	Rank, from farthest to nearest	1	2	3	Groton is proposed SEAWOLF homeport
Environmental Factors Affecting Operations					
Water depth of 152 m (500 ft)	Portion of area meeting criterion: 0 = 0% 1 = 1-49% 2 = 50-74% 3 = 75-99% 4 = 100%	4	4	4	By definition, all areas meet this requirement.
Ship traffic	Rank, from highest to lowest density	3	1	2	Mayport has about half as much commercial ship traffic as Norfolk or Groton. Norfolk has the highest density of military ship traffic.
Sea state [average occurrence of seas ≤1.8 m (≤6 ft)]	0 = <10% 1 = 10-24% 2 = 25-49% 3 = 50-75% 4 = >75%	4	4	3	
Incidence of fog (average)	0 = >15% 1 = 11-15% 2 = 6-10% 3 = 1-5% 4 = <1%	4	3	0	Groton has up to 26.6% incidence of fog during summer months, which could delay testing.
TOTAL SCORE (higher is better)		**36**	**34**	**24**	

points along the 152 m (500 ft) depth contour are considered potential shock testing locations.

At the Norfolk area, the portion of the 152 m (500 ft) depth contour passing through the proposed Norfolk Canyon Marine Sanctuary, along with a 4.6 km (2.5 nmi) buffer on either side, was excluded. The entire area north of the proposed sanctuary was eliminated due to the presence of several shipwrecks near the area. All remaining points along the 152 m (500 ft) depth contour are considered potential shock testing sites.

5.3 COMPARISON OF ALTERNATIVES

Table 5-4 summarizes the analysis of alternatives with respect to project purpose and need, operational criteria, and environmental impacts. The "no action" alternative (including computer modeling and component testing) is not a reasonable alternative because it would not provide the information and data necessary to support an assessment of the survivability of the ship in accordance with 10 USC 2366. Operational comparison of alternative areas for shock testing showed that the Mayport and Norfolk areas meet all of the Navy's operational requirements and are rated as nearly equal.

Potential environmental impacts of shock testing at the Mayport and Norfolk alternative areas are compared in **Table 5-5** and discussed in the Environmental Consequences section of the DEIS. Most environmental impacts of shock testing would be similar at Mayport or Norfolk. These include minor and/or temporary impacts to the physical and biological environments and existing human uses of the area. However, the two areas differ significantly with respect to potential impacts on marine mammals. Because of the difference in marine mammal densities between the two areas, the number of marine mammals potentially affected by the detonations would be about eight times lower at Mayport than at Norfolk. The number of turtles potentially affected would be about the same at either area. Considering all components of the physical, biological, and socioeconomic environment, potential impacts would be less at the Mayport area.

5.4 PREFERRED ALTERNATIVE

The preferred alternative is to shock test the SEAWOLF submarine offshore of Mayport, Florida, between 1 May and 30 September with mitigation to minimize risk to marine mammals and turtles. This alternative meets the project purpose and need, satisfies operational criteria, and minimizes environmental impacts. The Norfolk area also meets the project purpose and need and satisfies operational criteria; however, the higher density of marine mammals in the area could increase the risk of impacts.

Table 5-4. Summary of alternatives analysis.

Basis for Comparison	Alternative			
	No Action (Includes Maximum Reasonable Amount of Computer Modeling and Component Testing)	**Shock Testing at an Offshore Location**		
		Groton	Mayport	Norfolk
Meets project purpose and need	No	Yes	Yes	Yes
Meets operational criteria	No further analysis (alternative does not meet project purpose and need)	No	Yes	Yes
Potential environmental impacts	No further analysis (alternative does not meet project purpose and need)	No further analysis (alternative does not meet operational requirements)	Less risk of impacts to marine mammals at Mayport. Other impacts similar at the two sites. **See Table 5-5 for details.**	

Table 5-5. Comparison of potential environmental impacts of shock testing at the Mayport and Norfolk areas.

Environmental Component	Section of DEIS Analyzing Potential Impacts	Description of Potential Impact	Comparison of Alternative Areas
IMPACTS EVALUATED UNDER NEPA [a] (impacts onshore and within U.S. territorial seas)			
Physical Environment	4.1.1	No significant direct or indirect impacts on geology and sediments, air quality and noise, or water quality.	Mayport and Norfolk similar.
Biological Environment	4.1.2	No significant direct or indirect impacts on marine biota, including plankton, pelagic fish, marine mammals, sea turtles, benthic organisms, and seabirds.	Mayport and Norfolk similar.
Socioeconomic Environment	4.1.3	No significant direct or indirect impacts on the local economy, including ship traffic and the fishing and tourism industries.	Mayport and Norfolk similar.
IMPACTS EVALUATED UNDER EXECUTIVE ORDER 12114 (impacts outside U.S. territorial seas)			
Physical Environment			
Geology and sediments	4.2.1.1	Metal fragments will be deposited on the seafloor. No cratering or sediment disturbance expected.	Mayport and Norfolk similar.
Air quality	4.2.1.2	Temporary, localized increase in concentrations of explosion products in the atmosphere. No hazard to marine or human life.	Mayport and Norfolk similar.
Water quality	4.2.1.3	Temporary, localized increase in concentrations of explosion products in the ocean. No hazard to marine life.	Mayport and Norfolk similar.

Table 5-5. (Continued).

Environmental Component	Section of DEIS Analyzing Potential Impacts	Description of Potential Impact	Comparison of Alternative Areas
Biological Environment			
Plankton	4.2.2.1	Plankton near the detonation point would be killed, but populations would be rapidly replenished through reproduction and mixing with adjacent waters.	Mayport and Norfolk similar.
Fish	4.2.2.2	Pelagic (water column) fish near the detonation point may be killed or injured. Many of the same species occur at both areas. Demersal (bottom) fish will not be affected.	Mayport and Norfolk similar.
Marine mammals	4.2.2.3	Mitigation will minimize risk, but marine mammals could be killed or injured if not detected within the safety range. At greater distances, animals may experience brief acoustic discomfort, with no lasting effects expected.	Much less risk of impacts at Mayport because marine mammal densities are much lower there.
Sea turtles	4.2.2.4	Mitigation will minimize risk, but turtles could be killed or injured if not detected within the safety range. At greater distances, turtles may experience brief acoustic discomfort, with no lasting effects expected.	Mayport and Norfolk similar. Testing would not occur at Mayport during April when turtle densities are higher.
Benthos	4.2.2.5	No direct effect on benthic organisms is expected. No habitat disturbance is expected. Metal fragments deposited on the seafloor will be colonized by invertebrates and attract fish.	Mayport and Norfolk similar.

Table 5-5. (Continued).

Environmental Component	Section of DEIS Analyzing Potential Impacts	Description of Potential Impact	Comparison of Alternative Areas
Seabirds	4.2.2.6	Seabirds above the detonation point could be killed or stunned by the plume of water ejected into the air. Other seabirds resting or feeding at the surface could be killed or injured by the shock wave. It is unlikely that more than a few birds would be affected.	Mayport and Norfolk similar.
Socioeconomic Environment			
Commercial and recreational fisheries	4.2.3.1	Individuals of commercial or recreational fishery species may be killed or injured, but no significant impact on fishery stocks is expected. Commercial and recreational fishing activities within 18.5 km (10 nmi) of the detonation point will be temporarily interrupted.	Mayport and Norfolk similar.
Ship traffic	4.2.3.2	Ship traffic passing within 18.5 km (10 nmi) of the detonation point would need to alter course or be escorted from the area.	Mayport and Norfolk similar.

[a] Shore support operations and movement of vessels and aircraft within territorial seas are not unusual or extraordinary and are part of the routine operations associated with the existing shore bases.

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APPENDIX A

1995 AERIAL SURVEYS OF MARINE MAMMALS AND SEA TURTLES AT THE MAYPORT AND NORFOLK SITES

APPENDIX A

1995 AERIAL SURVEYS OF MARINE MAMMALS AND SEA TURTLES AT THE MAYPORT AND NORFOLK SITES

A.1 INTRODUCTION

Between April and September 1995, six aerial surveys of the Mayport and Norfolk sites were completed to estimate the density of marine mammals and sea turtles. Survey data were used to support development of the Draft Environmental Impact Statement (Department of the Navy, 1996) and associated permit requests (e.g., Request for Letter of Authorization). Details of the surveys are outlined in the following sections. Survey results are presented in Department of the Navy (1995).

A.2 SURVEY LOCATIONS

The two sites lie along the 152 m (500 ft) depth contour within a 185 km (100 nmi) radius of naval facilities at Mayport, Florida and Norfolk, Virginia (**Figures A-1** and **A-2**). Along the Atlantic coast in these areas, this bathymetric contour represents the continental shelf edge (Abernathy, 1989).

Within the Norfolk survey area, the northern limit was established just south of the proposed Norfolk Canyon National Marine Sanctuary [National Oceanic and Atmospheric Administration (NOAA), 1990]. The sanctuary and the area to the north were excluded due to environmental concerns with the sanctuary waters and the presence of a number of shipwrecks. The survey area thus extended from latitude 36°56.00'N to 35°41.00'N. All survey flights were staged from the Elizabeth City-Pasquotank County Municipal Airport, Elizabeth City, North Carolina.

The Mayport survey area extended from latitude 31°25.00'N to 29°01.00'N. All survey flights were staged from the Glynco-Taj Jetport in Brunswick, Georgia.

A.3 SURVEY METHODOLOGY

Standard line transect aerial surveying methods for marine mammals and sea turtles, as developed and approved by the National Marine Fisheries Service (NMFS), were adopted for the surveys (Blaylock, 1994). These methods use observers on both sides of the survey aircraft who, along predetermined transect lines, scan a swath of sea surface which is limited only by the effective angle of view from the aircraft's viewing port or window, and sea state. The total area viewed during each survey was 2,948 km^2 (858 nmi^2) at the Mayport site and 1,470 km^2 (428 nmi^2) at the Norfolk site.

Survey transects within the two survey areas were set up from east to west and with 1.85 km (1 nmi) line spacing, using current NOAA bathymetric maps and navigation charts. Based upon the limitations of fuel which could be carried by the survey aircraft, transit and per transect flight time, number of transects per survey area, estimates of time allotted for orbiting groups of animals, and expected observer fatigue, it

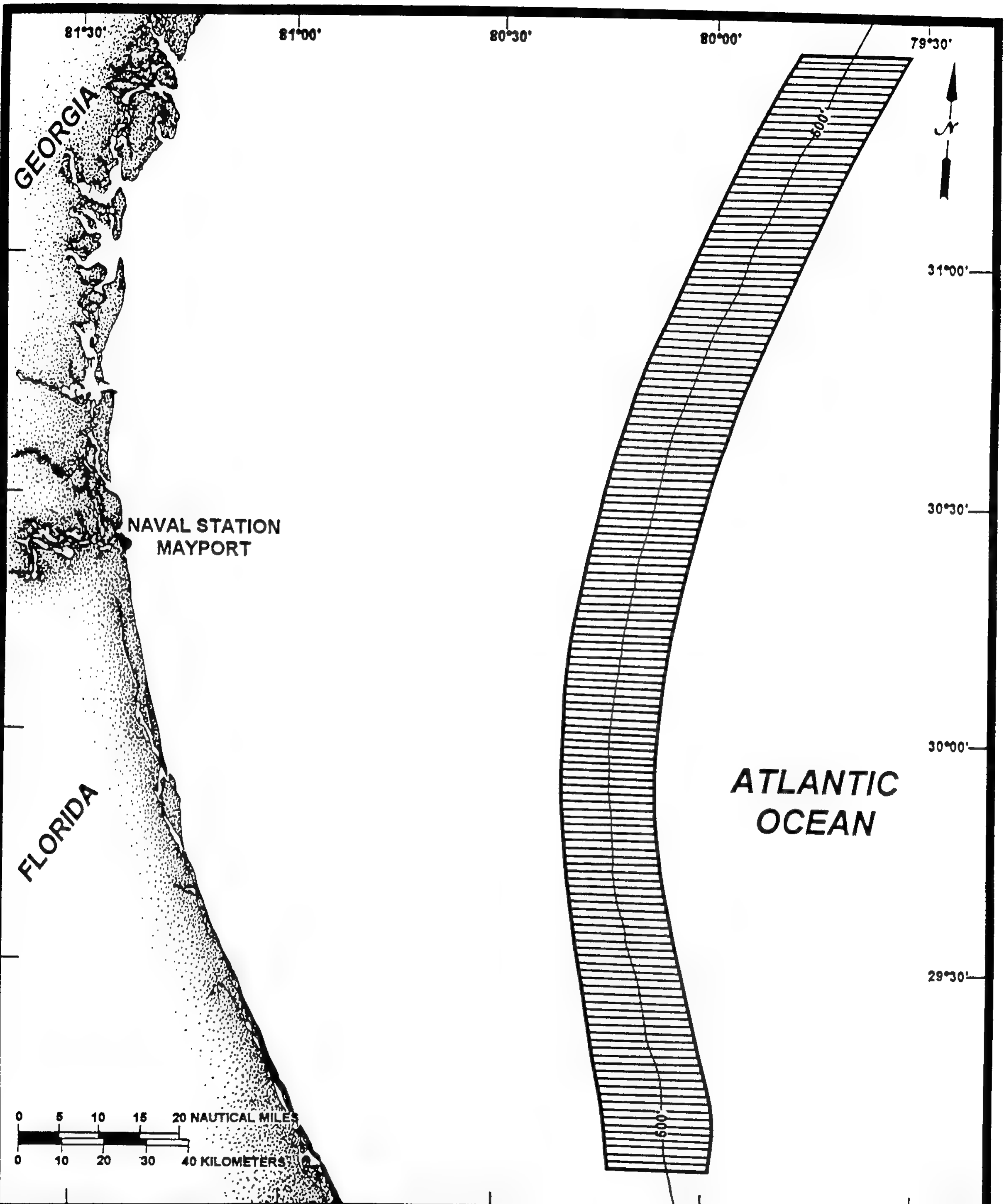

Figure A-1. Location of Mayport aerial survey area showing transects relative to the 152 m (500 ft) depth contour.

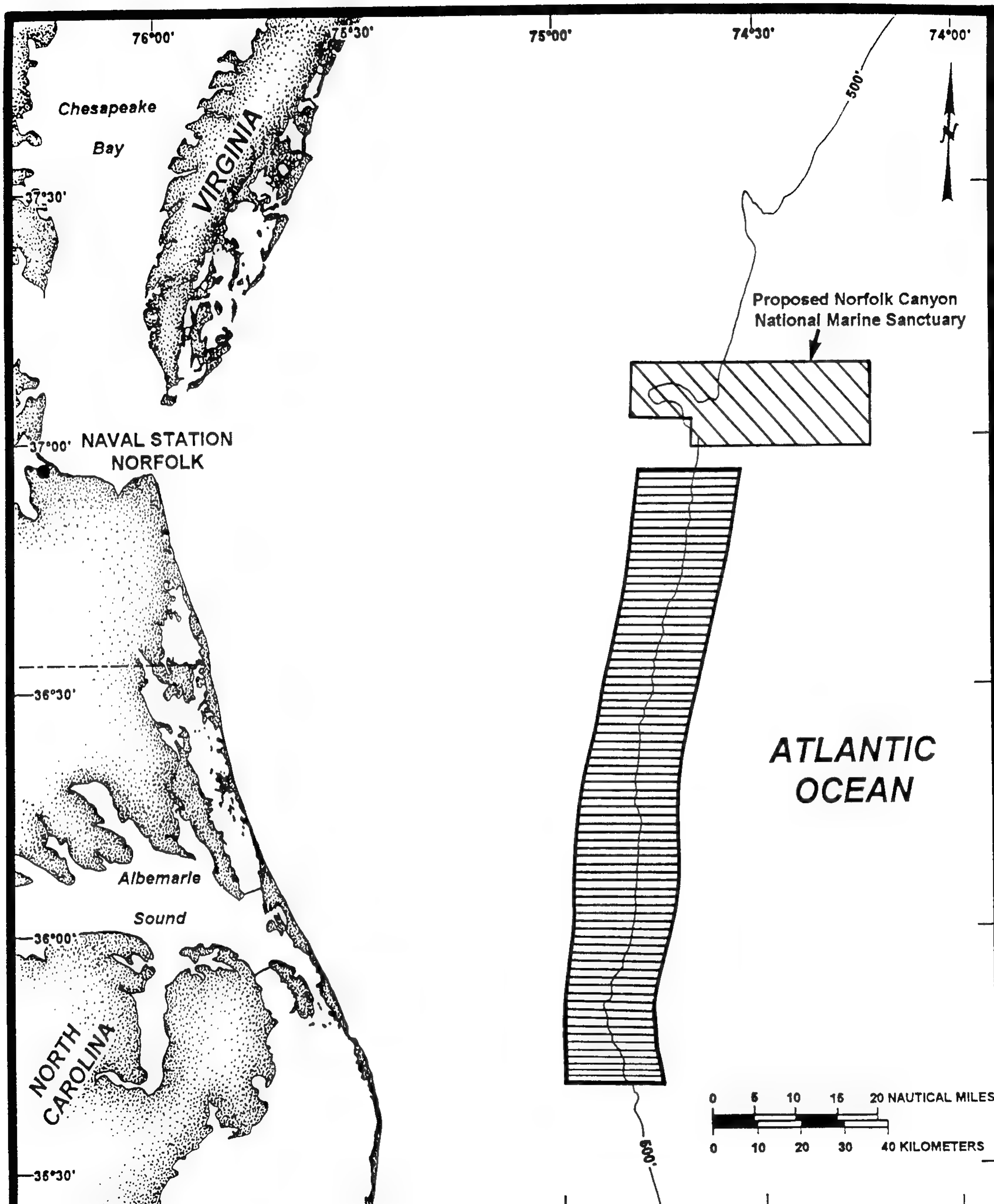

Figure A-2. Location of Norfolk aerial survey area showing transects relative to the 152 m (500 ft) depth contour.

was calculated that approximately 25 transects could be completed in one day. Therefore, the Norfolk survey area required three days for completion and the Mayport survey area six days for completion.

A Cessna C-337G Skymaster twin-engine aircraft, provided by Aero-Marine Surveys, Inc. (New London, Connecticut), was used as the survey platform (**Figure A-3**). A portable computer was interfaced with the onboard LORAN C receiver to collect navigation and supplemental survey data at one minute intervals while on transect. Navigation data included aircraft location (latitude and longitude), speed, course, and altitude. Supplemental data included survey area, transect number, estimates of weather conditions, sea state, and water clarity, and the extent of visual hindrance resulting from sunlight glare on the sea surface. An onboard radiation thermometer was also interfaced with the onboard computer to collect sea surface temperature data at each navigation fix (Thompson and Shoop, 1983; Schroeder and Thompson, 1987). The LORAN receiver was calibrated against an onboard Global Positioning System (GPS) receiver prior to each survey flight. This calibration was done at the same position on the airport taxiway each day. Similarly, the onboard radiation thermometer was calibrated using water tanks of known temperatures subsequent to each survey flight.

According to NMFS, the standard altitudes for marine mammal and sea turtle surveys are 229 m (750 ft) and 152 m (500 ft), respectively (Hoggard, 1994; Mullin, 1994). It was suggested that the surveys be conducted at an altitude of 198 m (650 ft), an altitude which is considered by NMFS as the optimum compromise when conducting simultaneous surveys for both marine mammals and sea turtles. However, based on further discussions between the Navy and NMFS, it was decided that conducting the combined aerial survey at an altitude of 229m (750 ft) was acceptable. Therefore, all transects were surveyed at an altitude of 229 m (750 ft) and a speed of 127 mi/h (110 kn).

Surveys were generally conducted between 0800 and 1500 h for maximum light penetration below the sea surface. Two observers were seated in the rear of the aircraft, using the forward and second side windows for scanning. The data logger sat opposite the pilot. This method is commonly used by NMFS during aerial surveys (NMFS, 1991, 1992). Along each survey transect, the observers continually scanned the sea surface in a roughly circular pattern. This strategy allowed for observation of distant sea surface disturbances caused by marine mammals, approaching animals, and detailed close up views abeam and abaft the beam of the aircraft. The effective sighting angles from the aircraft while on transect are shown in **Figure A-4**. Blind areas below the aircraft are shown as shaded voids. The effective vertical sighting angles, or visual transect swath, were approximately 45° to 65°.

The horizontal sighting angle was approximately 90°, or 45° forward and aft of the beam. The vertical and horizontal width of the transect swath varied inversely with local sea state conditions and sunlight glare; that is, observers tended to narrow their scan when sea conditions increased or during conditions of glare hindrance. As shown in **Figure A-4**, a substantial visual overlap between transects was attained during periods of low sea state and glare.

MISSION DATA (TYPICAL)

FLIGHT CREW: 1
SCIENTIFIC PARTY: 3
CRUISE SPEED: 130 KNOTS
ENDURANCE: 7.8 HOURS
RESERVES (VFR,DAY): 0.7 HOURS
TRACK LINE MILEAGE: 1,014 NAUTICAL MILES

MANUFACTURER: CESSNA
REGISTRATION: N700AM
TYPE: C-337G
ENGINE (2 EACH): CONT. IO-360-G
SERVICE CEILING: 18,000 FEET

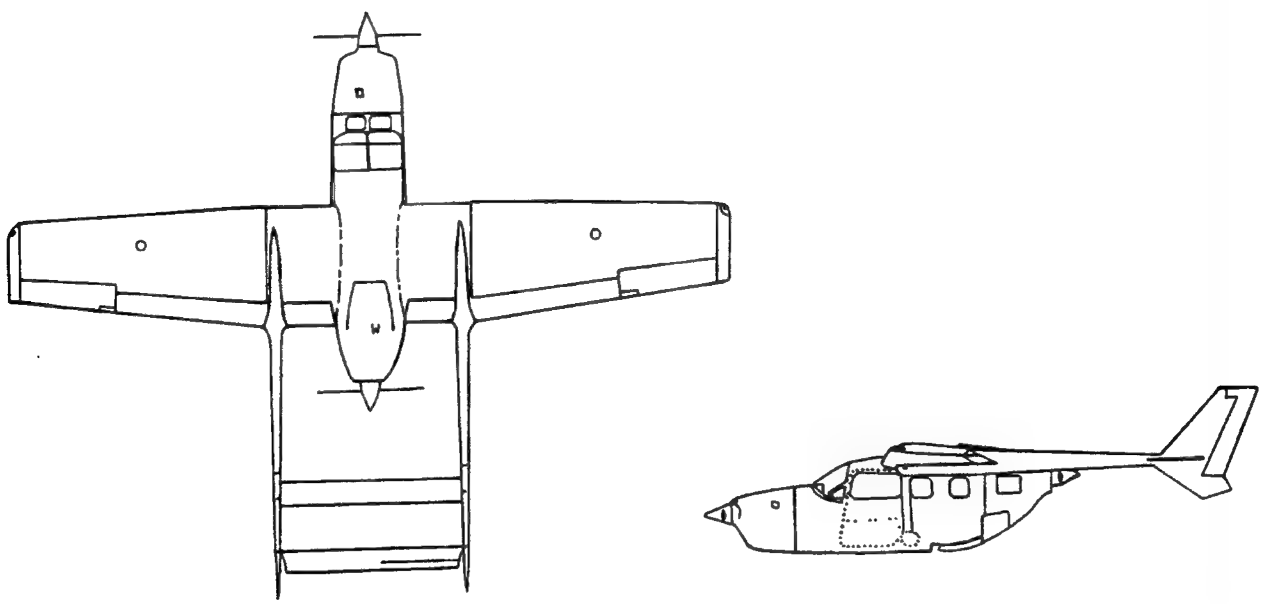

Figure A-3. Cessna multi-engine survey aircraft specifications.

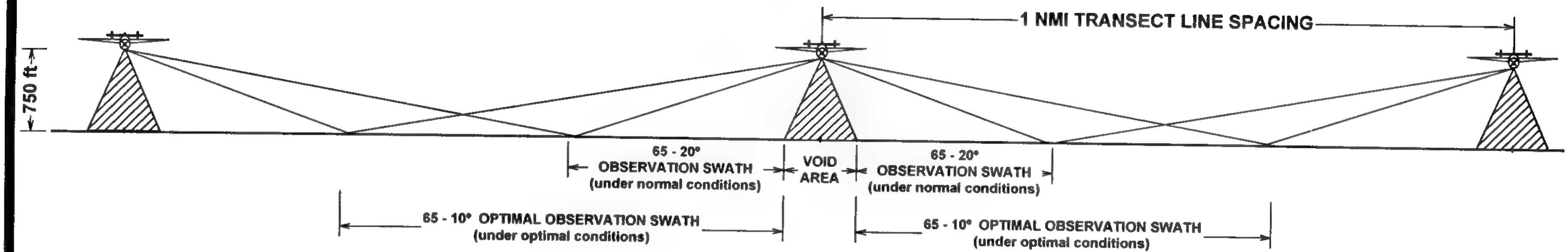

Figure A-4. Transect observation swaths from survey aircraft under normal and optimal sighting conditions. Distances to scale.

When an individual animal or group of animals was sighted, the observer would determine the perpendicular sighting distance of the sighting using a hand-held inclinometer (Suunto Model PM-5) (Musick et al., 1987; Barlow et al., 1988; Forney et al., 1991; Blaylock and Hoggard, 1994). Using the aircraft's intercom, the observer would then request a navigation fix, state animal type and approximate group number, and request, if deemed necessary for the determination of species identification(s), that the aircraft break transect and circle (i.e., orbit) for a closer examination. The pilot would, in the case of nonendangered marine mammals, lower altitude to approximately 183 m (600 ft) and return to the sighting fix. The marine mammal group in question was orbited until the identification of species was made and an accurate number of individuals assessed. Endangered marine mammals were, if possible, identified while on transect, or circled once at the survey altitude of 229 m (750 ft). Observations of individual or group behavior were also made during this time. Data relating to each sighting, along with exact location of the aircraft, transect number, observer, and location of the sighting in relation to the aircraft, were recorded onto data sheets by the data logger. After identification, the aircraft returned to the previous break position on the transect line and continued to survey.

Aerial surveys were usually conducted at a Beaufort sea state of 3 or less, which allows for the most accurate sighting and identification of individual marine mammals or sea turtles. Surveys were typically suspended when the Beaufort sea state exceeded 3 during the transit to the survey area or during the course of the survey.

A.4 PERMITS

All aerial surveys were conducted under the appropriate permits and authorizations or with specific permission from NMFS.

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APPENDIX B

ADJUSTED DENSITY AND MITIGATION EFFECTIVENESS CALCULATIONS FOR MARINE MAMMALS

APPENDIX B

ADJUSTED DENSITY AND MITIGATION EFFECTIVENESS CALCULATIONS FOR MARINE MAMMALS

B.1 ADJUSTMENT OF MARINE MAMMAL DENSITIES FOR SUBMERGED AND UNDETECTED INDIVIDUALS

Six aerial surveys were conducted at the Mayport and Norfolk areas during 1995 to estimate densities of marine mammals. Densities calculated from these aerial observations do not take into account submerged individuals or those that may have been on the surface but undetected. Therefore, adjusted densities were developed for each species seen during the surveys. Adjusted densities were calculated as follows:

$$D_{adj} = D_{obs}/P$$

where D_{adj} is the adjusted density, D_{obs} is the observed density, and P is the proportion of the total population believed to be detected by the aerial surveys. P was calculated as follows:

$$P = S_t \times ADP$$

where S_t is the probability of an animal being on the surface at any given time, and ADP is the aerial detection probability (the probability that an individual on the surface would be detected from the air).

Probabilities of being on the surface (S_t) were estimated by reviewing literature on the dive times of cetaceans and by consulting with marine mammal experts. All of the values for individual species were either 0.1 or 0.2 (i.e., the animals spend most of the time submerged). Aerial detection probabilities (ADP) were estimated based on animal length and herding tendencies. It was assumed that larger animals and those that tend to occur in groups would have a higher probability of detection. Each species was scored using the following scales:

Length	Herding
0 = <1 m (<3 ft)	0 = Not likely
1 = 1-1.5 m (3-5 ft)	1 = Somewhat likely
2 = 1.8-3 m (6-10 ft)	2 = Likely
3 = 3.4-5.5 m (11-18 ft)	3 = Very likely
4 = 5.8-7.6 m (19-25 ft)	4 = Highly likely
5 = >7.6 m (>25 ft)	

For each species, the length and herding scores were summed and a corresponding ADP was assigned as follows:

Sum of Length and Herding Scores	Aerial Detection Probability (ADP)
0	0.1
1	0.3
2	0.5
3-4	0.7
5-9	0.9

Table B-1 summarizes the results of these calculations. The table shows mean densities for the six-month survey period (April through September 1995). Because there would be no shock testing in April at Mayport, mean densities for Mayport were also calculated for the May-September period (i.e., excluding April). The estimated proportion of the population detected (P) ranged from 0.09 to 0.18. Therefore, adjusted densities were estimated to be 6 to 11 times higher than observed densities.

B.2 MITIGATION EFFECTIVENESS CALCULATIONS FOR MARINE MAMMALS

The marine mammal and sea turtle mitigation plan (see LOA Section 4.0) includes the use of aerial and shipboard observers and passive acoustic surveys to detect marine mammals within the safety range prior to detonation. For impact analysis, it was necessary to estimate mitigation effectiveness, i.e., the probability of detecting an animal if present.

Mitigation effectiveness was estimated separately for each component (aerial monitoring, surface monitoring, and passive acoustic monitoring), then combined. The approach to estimating mitigation effectiveness was based on previous environmental assessments (Department of the Navy, 1993, 1994) and reviewed by marine mammal experts.

B.2.1 Aerial Monitoring

For aerial monitoring, mitigation effectiveness (ME) was calculated as follows:

$$ME_{aerial} = ADP \times S_{aerial}$$

where ADP is aerial detection probability as defined previously, and S_{aerial} is the probability of an animal being on the surface at least once during aerial monitoring. S_{aerial} is not the same as S_t, which was used to adjust 1995 aerial survey data as discussed above. Unlike the 1995 surveys, aerial monitoring would include three complete passes over the site: one pass 2.5 hours prior to detonation, and two passes (line transects and concentric circles) within 1 hour prior to detonation (see LOA Section 4.0). Therefore, the probability of being on the surface during at least one pass is higher than for the 1995 aerial surveys, which consisted of a single pass over each transect.

Using the S_t values from Table B-1 to represent the probability of an animal being on the surface at any given time, the probability of an animal being on the

Table B-1. Adjustment of 1995 aerial survey data to account for submerged and undetected marine mammals.

Species	Probability of Being on Surface (S_t)	Aerial Detection Calculations			Proportion of Population Detected ($P = S_t \times ADP$)	Mayport Densities[a] All Six Surveys (Individuals/100 km^2)		Mayport Densities[a] Excluding April (Individuals/100 km^2)		Norfolk Densities[a] All Six Surveys (Individuals/100 km^2)	
		Length Score	Herding Score	Aerial Detection Probability (ADP)		Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)	Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)	Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)
BALEEN WHALES											
Fin whale (E)	0.2	5	2	0.9	0.18	0	0	0	0	0.52	2.90
Humpback whale (E)	0.2	5	3	0.9	0.18	0	0	0	0	0.01	0.06
Minke whale	0.1	5	1	0.9	0.09	0	0	0	0	0.02	0.25
Sei whale (E)	0.2	5	2	0.9	0.18	0	0	0	0	0.02	0.13
Sei/Bryde's whale	0.2	5	2	0.9	0.18	0	0	0	0	0.01	0.06
Unidentified *Balaenoptera* spp.	0.2[b]	5	NA	0.9[b]	0.18	0	0	0	0	0.14	0.76
Unidentified large whale	0.2[b]	5	NA	0.9[b]	0.18	0	0	0	0	0.05	0.25
TOOTHED WHALES AND DOLPHINS											
Atlantic spotted dolphin	0.2	2	4	0.9	0.18	0.88	4.90	0.52	2.90	9.34	51.90
Bottlenose dolphin	0.2	2	3	0.9	0.18	1.39	7.70	0.53	2.94	5.83	32.38
Bottlenose/Atlantic spotted dolphin	0.2	2	3	0.9	0.18	0.15	0.82	0.18	0.98	0.73	4.03
Clymene/spinner/striped dolphin	0.2	2	4	0.9	0.18	0.25	1.38	0.13	0.72	2.78	15.43
Common dolphin	0.2	2	4	0.9	0.18	0	0	0	0	3.51	19.53
Cuvier's beaked whale	0.1	4	2	0.9	0.09	0	0	0	0	0.02	0.25
Pantropical spotted dolphin	0.2	2	4	0.9	0.18	2.19	12.15	1.55	8.63	4.93	27.40
Pilot whale[c]	0.2	3	3	0.9	0.18	0	0	0	0	15.60	86.67

Table B-1. (Continued).

Species	Probability of Being on Surface (S_t)	Aerial Detection Calculations			Proportion of Population Detected ($P = S_t \times ADP$)	Mayport Densities[a] All Six Surveys (Individuals/100 km^2)		Mayport Densities[a] Excluding April (Individuals/100 km^2)		Norfolk Densities[a] All Six Surveys (Individuals/100 km^2)	
		Length Score	Herding Score	Aerial Detection Probability (ADP)		Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)	Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)	Observed Mean Density (D_{obs})	Adjusted Mean Density ($D_{adj} = D_{obs}/P$)
Risso's dolphin	0.2	3	3	0.9	0.18	1.10	6.12	1.19	6.60	1.35	7.50
Sperm whale (E)	0.1	5	2	0.9	0.09	0.01	0.13	0.01	0.15	0.05	0.50
Spinner dolphin	0.2	2	4	0.9	0.18	0.28	1.57	0.34	1.88	0.70	3.91
Striped dolphin	0.2	2	4	0.9	0.18	0	0	0	0	0.27	1.51
Unidentified dolphin	0.2[b]	NA	NA	0.9[b]	0.18	1.12	6.22	1.28	7.09	4.38	24.31
Unidentified small whale	0.2[b]	NA	NA	0.9[b]	0.18	0	0	0	0	0.06	0.32
TOTAL MARINE MAMMALS						**7.37**	**40.99**	**5.73**	**31.89**	**50.32**	**280.05**

(E) = endangered species. NA = not applicable.

a Densities shown are rounded to two decimal places, but calculations were done using original, unrounded data. Some values may differ slightly from those one could calculate using the tabulated numbers.
b Composite values were assigned for unidentified species.
c The two species of pilot whales in the western Atlantic, the long-finned pilot whale (*Globicephala melaena*) and short-finned pilot whale (*G. macrorhynchus*), are difficult to differentiate in the field and have been combined in this analysis.

surface during at least one of three passes can be estimated using binomial theory (Winkler and Hays, 1975):

$$P \text{ (on surface at least once in three trials)} = 1 - (1 - S_t)^3$$

For S_t = 0.2 (the most common value in Table B-1), this yields a value of 0.49 for S_{aerial}. In other words, if there is a 0.2 probability of being on the surface during a single pass, there is a 0.49 probability of being on the surface at least once during three passes.

This method assumes that the three passes during aerial monitoring would be independent sampling events. For short-diving species such as dolphins, small toothed whales, and many baleen whales, this is a reasonable assumption because individual animals could dive and surface several times between aerial passes. For large, deep-diving species (e.g., minke whale, sperm whale, and possibly Cuvier's beaked whale), an individual animal could be submerged on the same dive during successive passes, but the assumption would still be valid when applied to the population as a whole as long as dives of individual animals are independent. Because these whales have relatively low herding scores (Table B-1), this is a reasonable assumption.

Table B-2 shows the ADP and S_{aerial} values for each species. The product of these two values is the aerial mitigation effectiveness (ME_{aerial}) for each species.

B.2.2 Surface Monitoring

For aerial monitoring, mitigation effectiveness was calculated as:

$$ME_{surface} = SDP \times S_{surface}$$

where $S_{surface}$ is the probability of an animal being on the surface at least once during surface monitoring, and SDP is the probability that a species would be detected by surface observers, if present. The method for estimating SDP was similar to the approach described above for ADP, except that visibility enhancements such as leaping, blowing, spinning, and bow wave riding were also considered. Each species was scored using the following scales:

Length	Herding	Visibility Enhancements
0 = <1 m (<3 ft)	0 = Not likely	0 = Very Poor
1 = 1-1.5 m (3-5 ft)	1 = Somewhat likely	1 = Poor
2 = 1.8-3 m (6-10 ft)	2 = Likely	2 = Low
3 = 3.4-5.5 m (11-18 ft)	3 = Very likely	3 = Average
4 = 5.8-7.6 m (19-25 ft)	4 = Highly likely	4 = Significant
5 = >7.6 m (>25 ft)		5 = Conspicuous

Table B-2. Estimated mitigation effectiveness of aerial monitoring for marine mammals.

Species	Length Score	Herding Score	Aerial Detection Probability (ADP)[a]	Probability of Being on Surface (S_{aenal})	Aerial Mitigation Effectiveness (ME_{aenal})[b]
BALEEN WHALES					
Fin whale (E)	5	2	0.9	0.49	0.44
Humpback whale (E)	5	3	0.9	0.49	0.44
Minke whale	5	1	0.9	0.27	0.24
Sei whale (E)	5	2	0.9	0.49	0.44
Sei/Bryde's whale	5	2	0.9	0.49	0.44
Unidentified *Balaenoptera* spp.	5	2	0.9	0.49	0.44
Unidentified large whale	NA	NA	0.9[c]	0.49	0.44
TOOTHED WHALES AND DOLPHINS					
Atlantic spotted dolphin	2	4	0.9	0.49	0.44
Bottlenose dolphin	2	3	0.9	0.49	0.44
Bottlenose/Atl. spotted dolphin	2	3	0.9	0.49	0.44
Clymene/spinner/striped dolphin	2	4	0.9	0.49	0.44
Common dolphin	2	4	0.9	0.49	0.44
Cuvier's beaked whale	4	2	0.9	0.27	0.24
Pantropical spotted dolphin	2	4	0.9	0.49	0.44
Pilot whale	3	3	0.9	0.49	0.44
Risso's dolphin	3	3	0.9	0.49	0.44
Sperm whale (E)	5	2	0.9	0.27	0.24
Spinner dolphin	2	4	0.9	0.49	0.44
Striped dolphin	2	4	0.9	0.49	0.44
Unidentified dolphin	NA	NA	0.9[c]	0.49	0.44
Unidentified small whale	NA	NA	0.9[c]	0.49	0.44

(E) = endangered species. NA = not applicable.

a ADP depends on sum of length and herding scores (see text).
b ME_{aerial} = ADP x S_{aerial}.
c Composite values were assigned for unidentified species.

For each species, the length, herding, and visibility enhancement scores were summed and a corresponding SDP was assigned as follows:

Sum of Length, Herding, and Visibility Scores	Surface Detection Probability (SDP)
0	0
1	0.1
2	0.3
3	0.5
4-5	0.7
6-14	0.9

The other term in the equation, $S_{surface}$, is not the same as S_t, which was used to adjust 1995 aerial survey data. Unlike the 1995 aerial surveys, surface monitoring would include continuous observations during at least 2.5 hours prior to detonation (see Section 4.0). Depending on weather conditions, the observers could detect marine mammals out to 4 to 6 nmi from the detonation point. $S_{surface}$ therefore refers to the probability that an animal would be on the surface within 4 to 6 nmi of the detonation point at least once during the 2.5 hours preceding detonation. In order to be not detectable by surface observers, an animal would have to be submerged during the entire time it was present in the area.

Typical dive times for dolphins, small toothed whales, and many baleen whales are on the order of several minutes (Jefferson et al., 1993; Ridgway and Harrison, 1994; Tyack, 1996). It is reasonable to assume that if these animals were present in the area, they would probably be on the surface at least once during the 2.5 hours preceding detonation. Therefore, an $S_{surface}$ value of 0.95 was assigned to these animals.

Some species such as minke and sperm whales and possibly Cuvier's beaked whale can have longer dive times; dives of up to 2 hours have been reported for sperm whales (Jefferson et al., 1993). The probability of being on the surface at least once during 2.5 hours is obviously higher than the surface probability (S_t) listed in Table B-1. A conservative assumption is that $S_{surface}$ for these species would be no less than S_{aerial} defined above, which is based on three independent aerial passes rather than continuous surface observations. The following values were assigned:

- Dolphins and small toothed whales: $S_{surface} = 0.95$
- Baleen whales (except minke): $S_{surface} = 0.95$
- Minke, Cuvier's, sperm whale: $S_{surface} = S_{aerial} = 0.27$

Table B-3 shows the SDP and $S_{surface}$ values for each species. The product of these two values is the surface mitigation effectiveness ($ME_{surface}$) for each species.

Table B-3. Estimated mitigation effectiveness of surface monitoring for marine mammals.

Species	Length Score	Herding Score	Visibility Enhance-ments Score	Surface Detection Probability (SDP)[a]	Probability of Being on Surface ($S_{surface}$)	Surface Mitigation Effectiveness ($ME_{surface}$)[b]
BALEEN WHALES						
Fin whale (E)	5	2	3	0.9	0.95	0.855
Humpback whale (E)	5	3	5	0.9	0.95	0.855
Minke whale	5	1	2	0.9	0.27	0.24
Sei whale (E)	5	2	3	0.9	0.95	0.855
Sei/Bryde's whale	5	2	4	0.9	0.95	0.855
Unidentified *Balaenoptera* spp.	5	2	3	0.9	0.95	0.855
Unidentified large whale	5	NA	NA	0.9[c]	0.95[c]	0.855
TOOTHED WHALES AND DOLPHINS						
Atlantic spotted dolphin	2	4	3	0.9	0.95	0.855
Bottlenose dolphin	2	3	3	0.9	0.95	0.855
Bottlenose/Atl. spotted dolphin	2	3	3	0.9	0.95	0.855
Clymene/spinner/striped dolphin	2	4	3	0.9	0.95	0.855
Common dolphin	2	4	3	0.9	0.95	0.855
Cuvier's beaked whale	4	2	2	0.9	0.27	0.24
Pantropical spotted dolphin	2	4	3	0.9	0.95	0.855
Pilot whale	3	3	2	0.9	0.95	0.855
Risso's dolphin	3	3	3	0.9	0.95	0.855
Sperm whale (E)	5	2	4	0.9	0.27	0.24
Spinner dolphin	2	4	4	0.9	0.95	0.855
Striped dolphin	2	4	3	0.9	0.95	0.855
Unidentified dolphin	NA	NA	NA	0.9[c]	0.95	0.855
Unidentified small whale	NA	NA	NA	0.9[c]	0.95	0.855

(E) = endangered species. NA = not applicable.

a SDP depends on sum of length, herding, and visibility enhancements scores (see text).
b $ME_{surface} = SDP \times S_{surface}$.
c Composite values were assigned for unidentified species.

B.2.3 Passive Acoustic Monitoring

The passive acoustic monitoring system described in Section 4.0 is capable of detecting any marine mammal sounds within the safety range. The following values were estimated for acoustic detection probability (Tyack, 1996):

- Sperm whales and *Stenella* (Clymene, spinner, and striped dolphins) $ME_{acoustic} = 0.75$
- Other odontocetes except Cuvier's beaked whale: $ME_{acoustic} = 0.50$
- Baleen whales and Cuvier's beaked whale: $ME_{acoustic} = 0.25$

These estimates are based on the tendency of the animals to make detectable sounds. Sperm whales produce distinctive low-frequency clicked vocalizations, or "codas" (Jefferson et al., 1993) and are considered very likely to be detected acoustically if present in the area (Tyack, 1996). As indicated by the herding scores in Table B-2, most of the dolphins are highly social, and the presence of a school would almost certainly be accompanied by whistles, clicks, and other detectable sounds.

B.2.4 Combined Mitigation Effectiveness

Mitigation effectiveness for all three components (aerial, surface, and passive acoustic monitoring) would be greater than for any individual component. Aerial and surface monitoring would be expected to have the greatest overlap in detection, but it is difficult to estimate the extent of overlap. Therefore, it was conservatively assumed that overall visual mitigation effectiveness would be equal to the greater of the two (aerial or surface detection). The assumption is that there would be no gain by using the combination of aerial and surface observers.

$$ME_{visual} = \max(ME_{aerial}, ME_{surface})$$

Passive acoustic monitoring would improve overall mitigation effectiveness by detecting some proportion of the non-visually detected population ($1 - ME_{visual}$). Because acoustic monitoring is assumed to be independent of visual monitoring, the proportion detected would be equal to $ME_{acoustic}$, as defined above. Total mitigation effectiveness was therefore calculated as follows:

$$ME_{combined} = ME_{visual} + [ME_{acoustic} \times (1 - ME_{visual})]$$

For example, suppose 0.6 of the population would be detected aerially and 0.55 would be detected by surface observers. ME_{visual} would be the greater of the two, or 0.6. Therefore, 0.4 of the population would not be detected visually. Then suppose that passive acoustic monitoring detects 0.25 of the population, independent of whether the animals are visible to observers. Therefore, 0.25 of the "non-visible" animals would be detected acoustically. The additional proportion of the entire population detected acoustically would be 0.25 x 0.4 = 0.1. Combined mitigation effectiveness would therefore be 0.6 (visual) + 0.1 (acoustic) = 0.7 (total).

Table B-4 summarizes aerial, surface, acoustic, and combined mitigation effectiveness estimates. Combined mitigation effectiveness is estimated to range from 0.43-0.89 for baleen whales. Values are 0.93-0.96 for most dolphins and toothed whales; exceptions are sperm whale (0.81) and Cuvier's beaked whale (0.43).

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Table B-4. Summary of estimated mitigation effectiveness for marine mammals.

Species	Mitigation Effectiveness			
	Aerial (ME_{aerial})	Surface ($ME_{surface}$)	Acoustic ($ME_{acoustic}$)	Combined[a] ($ME_{combined}$)
BALEEN WHALES				
Fin whale (E)	0.44	0.855	0.25	0.89
Humpback whale (E)	0.44	0.855	0.25	0.89
Minke whale	0.24	0.24	0.25	0.43
Sei whale (E)	0.44	0.855	0.25	0.89
Sei/Bryde's whale	0.44	0.855	0.25	0.89
Unidentified *Balaenoptera* spp.	0.44	0.855	0.25	0.89
Unidentified large whale	0.44	0.855	0.25	0.89
TOOTHED WHALES AND DOLPHINS				
Atlantic spotted dolphin	0.44	0.855	0.50	0.93
Bottlenose dolphin	0.44	0.855	0.50	0.93
Bottlenose/Atlantic spotted dolphin	0.44	0.855	0.50	0.93
Clymene/spinner/striped dolphin	0.44	0.855	0.75	0.96
Common dolphin	0.44	0.855	0.50	0.93
Cuvier's beaked whale	0.24	0.24	0.25	0.43
Pantropical spotted dolphin	0.44	0.855	0.50	0.93
Pilot whale	0.44	0.855	0.50	0.93
Risso's dolphin	0.44	0.855	0.50	0.93
Sperm whale (E)	0.24	0.24	0.75	0.81
Spinner dolphin	0.44	0.855	0.75	0.96
Striped dolphin	0.44	0.855	0.75	0.96
Unidentified dolphin	0.44	0.855	0.50	0.93
Unidentified small whale	0.44	0.855	0.50	0.93

(E) = endangered species.

[a] Combined mitigation effectiveness was calculated as:
$ME_{combined} = ME_{visual} + [ME_{acoustic} \times (1 - ME_{visual})]$,
where ME_{visual} is equal to ME_{aerial} or $ME_{surface}$, whichever is greater.

APPENDIX C

POTENTIAL IMPACTS OF ACTIVITIES ON MARINE MAMMALS

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APPENDIX C

This appendix summarizes information on the effects of underwater explosions on marine mammals. A review of marine mammal anatomy and mechanisms for injury from underwater explosions is included. Results from experiments conducted mainly with terrestrial mammals are used to develop criteria and ranges for lethal and non-lethal injury. This information is used in the Environmental Consequences section of the DEIS.

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APPENDIX C

POTENTIAL IMPACT OF ACTIVITIES ON MARINE MAMMALS

Potential impacts to marine mammals include both lethal and non-lethal injuries as well as brief physical discomfort and acoustic annoyance. Most obviously, immediate injury or death could occur as a direct result of proximity to the point of detonation. Short term lethal injury would be a result of massive combined trauma to internal organs. Non-lethal injury includes slight injury to internal organs as well as to the auditory system; however, delayed lethality can be a result of complications from individual or cumulative sub-lethal injuries. Discomfort to and annoyance of marine mammals could occur as a result of non-injurious physiological response to both the explosion-generated shockwave as well as to the acoustic signature of the detonation. It is very unlikely that injury would occur from exposure to the chemical by-products released into the surface waters (Young, 1984; and NSWC, 1992).

A. The Effects of Underwater Explosions on Marine Mammals[1]

"Considerable information about the anatomy of marine mammals is available, particularly with regard to the adaptations necessary for survival in the underwater environment. The possible effects of underwater shock waves on these animals can be inferred from the similarities and differences in anatomy between marine and land mammals....

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[1] Section is largely excerpted from Hill (1978).

"All true marine mammals dive for food and are therefore adapted to changes in hydrostatic pressure.... The adaptations necessary to permit marine mammals to withstand the pressure changes involved in deep diving are found primarily in the air-filled spaces of the body - notably the lungs, respiratory passages, outer and middle ear and accessory sinuses. Since the air-filled spaces of the body are the primary sites of damage to land mammals by underwater shock waves, adaptations which allow marine mammals to tolerate pressure changes may also make them resistant to damage from shock waves," Hill (1978).

The actual vulnerability of marine mammals to underwater explosions is largely unknown -- only two reports[2] have been found which describe experiments involving cetaceans.

A.1. Thorax

The thorax of marine mammals is much more flexible than that of land mammals. Very few ribs are connected to the sternum with costal cartilage - especially in cetaceans - and the costal cartilage itself is flexible. Some odontocetes (toothed whales) have "floating ribs", unconnected either to the sternum or to other ribs. Such a loosely-connected thoracic cage may not reduce the effects of shock waves on the lungs, since a rigid shield may be necessary to afford considerable protection against damage.

[2] Todd, et al., 1993; and Myrick, et al., 1990.

A.2. Respiratory System

Respiratory passages and lungs of marine mammals, particularly cetaceans, are highly modified for diving.... Compared to terrestrial mammals, there is a striking increase in the amount of supportive structures, namely cartilage, collagen, smooth muscle and elastic tissue in the peripheral portions of the lung. Extensive supportive structures are also found in the upper airways. Cartilaginous support extends from the trachea into the smaller airways up to the junction with alveolar ducts. Dense layers of elastic tissue, just beneath the mucous membrane, encircle and connect the cartilage. All these supportive tissues probably make cetacean lungs and airways less vulnerable to damage by shock waves, since the boundaries between tissue and air are not as fragile as in land animals.

The lung structure of pinnipeds, especially seals, is more similar to that of land mammals, but there are other modifications of the respiratory system which are shared by both pinnipeds and cetaceans.... The lung size relative to body size of marine mammals does not differ much from that of land mammals. However, the ratio of tidal air volume to the total lung volume, and the ratio of air passage volume to the total air volume are higher for marine mammals. These are modifications for deep diving. Increased tidal air ratio means that more air in the lungs is renewed with each breath - facilitating rapid gas exchange. Larger relative air passage volume may permit total lung collapse during deep dives. Lungs are usually placed dorsally, and the diaphragm typically extends obliquely across the

thoracic cavity; thus, the lungs can completely flatten against the dorsal thoracic wall. The flexible thorax of these animals permits such a collapse, with the compressed air from the lungs being forced into the more rigid air passages....

Seals generally exhale before diving, or during the initial part of the dive, whereas some cetaceans have been observed to dive after inspiration. Thus, the diving depth at which total lung collapse occurs is probably less for pinnipeds than for cetaceans. Nevertheless, when the lungs are collapsed, they will certainly be less vulnerable to damage from shock waves. Upper air passages in land mammals (and probably marine mammals as well) are not primary damage sites.

A.3. Ears and Other Air-Spaces in the Head Region

The middle and outer ears, and the various sinuses associated with the ears of diving mammals also have protection against pressure changes. True seals (*Phocidae* - this group includes all the common seals of the Arctic) and cetaceans do not have any external ears. Instead, the external ear opening is usually a small pore or slit on the side of the head region. In pinnipeds, the external auditory canal is long and narrow and is supported by cartilage. The canal is also lined with a thick, highly vascularized "cavernous" tissue; it may expand during a dive by filling with blood and thus occupy the air-filled space in the canal. The seal's external ear-opening is usually closed while diving. Very dense bone surrounds the middle ear cavity, which is also lined with thick cavernous tissue, called the *corpus*

cavernosum. Seal biologists believe that this tissue fills with blood as the seal descends in order to equalize the air pressure within the middle ear cavity with the pressure in other ear passages connected to the inner ear via the eustachian tube.

In toothed whales, the external ear opening is very small, or closed entirely. The auditory canal and the middle ear are lined with cavernous tissue; the middle and inner ears are also surrounded by a system of air sinuses filled with a foam formed from an oil-mucous emulsion. These sinuses are bounded closely by the bones of the skull and by thick cavernous tissue. As in the pinniped ear, the cavernous tissue probably fills with blood as the animal dives, thus expanding into the cavity to equalize the internal air pressure with the external hydrostatic pressure.

It appears that the air spaces associated with the ears of pinnipeds and cetaceans are well protected against shock-wave damage, because these spaces are typically surrounded by bone or cartilage and are lined with cavernous tissue which is itself bounded by a tough, fibrous membrane. During deep dives, these air spaces might be reduced in size by filling of the cavernous tissue with blood. The eardrum of pinniped and baleen whales - it is not functional in toothed whales - may be damaged by shock waves. An injured animal may be partially incapacitated in this way, but it is not known to what extent pinnipeds and baleen whales rely on hearing for their survival. A ruptured eardrum could also cause a fatal secondary infection of the middle ear.

The highly modified nostrils (nares) of cetaceans contain additional air-containing sacs and passages. The lining of these passages is tough and elastic in sperm whales, and it seems possible that this is the case in all whales. If so, the nostrils are not likely to be principal sites of damage by shock waves.

A.4. Viscera

Other principal damage sites in *terrestrial* mammals are regions of hollow viscera containing gas.... Such gas bubbles are *probably* uncommon, since the presence of significant quantities of gas in the intestinal tracts of animals which spend a great deal of time passing through pressure differences of 20 atmospheres or more could cause considerable discomfort, pain, and even injury.

A.5. Skin and Body Walls

In the review of the effects of shock waves on terrestrial mammals, it is noted that larger animals are less vulnerable to damage than small animals. This is likely a function of the thicker body walls of the larger mammals. Most marine mammals are large animals, possessing thick body walls. The skin of cetaceans consists of a tough epidermis, usually less than 1 cm thick, under which is the thinner dermis, composed mainly of thick bundles of connective tissue. Below the dermis lies the hypodermis, or blubber, a layer of fatty tissue - up to 60 cm thick in larger whales. The skin of pinnipeds is similar, except that all layers are proportionately thinner. The blubber layer of the ringed seal ranges from 10 mm to 63 mm in thickness, depending on the size of the animal and the season. Arctic pinnipeds (except

walrus) also have a layer of fur which, along with the skin, is waterproofed by a thin film of oil.

(Measurements of) the acoustic properties of the blubber coat in porpoises (indicated that) although sound easily entered the blubber coat, "the blubber/muscle interface proved an excellent sound reflector." Shock waves are reflected and absorbed in a roughly similar manner to low amplitude sound waves. Thus, although only a small fraction of shock-wave energy would be reflected at the skin and water interface, a considerable fraction would be reflected at the blubber and muscle interface. This would correspondingly reduce the peak pressures of the shock wave entering the body of the animal. The unwettable skin and fur of pinnipeds would not be a good acoustic couple between the water and the body of the animal, and could reduce the intensity of a shock wave more than would the wet skin of cetaceans.

B. Injury from Underwater Explosions

"Events taking place during the reflection and absorption of shock waves at boundaries between two different media may cause death or damage when these boundaries are within living organisms. When a shock wave passes from tissue of one density to tissue of a different density (for example, from muscle to bone), the particle velocities imparted to these tissues will be different. If the peak pressure of the shock wave is high and the density difference between the tissues is large,

resulting in a large difference in particle velocity, the two tissues may be literally torn apart.

"Shock wave reflections at an interface between tissue and an air-filled cavity within a living organism can cause great damage to tissues at the interface. This situation is physically analogous to the reflection of an underwater shock wave from a water surface. If the peak pressure of the shock wave is high enough, a form of cavitation will occur within the tissue near the boundary. Tissue at this boundary will also explode into the air-space because of the high particle velocity normal to the boundary imparted by the reflecting shock wave. Pathological consequences of these two effects could be destruction of tissues, loss of integrity of the boundary, and possible haemorrhage if capillaries or blood vessels are present," (Hill, 1978).

During the early 1970's, numerous tests were conducted on terrestrial mammals to determine injury mechanism and injury tolerance from underwater explosions. General details on these tests are provided by Yelverton, et al. (1973). Specific explosion shockwave parameters and detailed pathological reports are provided by Richmond, et al. (1973). "[These and other] experiments have shown that the principal damage sites in mammals are the gas-containing organs - the most seriously affected major organs being the lungs and the hollow viscera.

"Lung injuries consist of the rupture of alveolar walls and lacerations of larger areas, with subsequent massive haemorrhage. Air emboli can also result when the boundaries between the alveolar spaces and adjacent capillary-beds rupture.

"Damage to the viscera is mainly restricted to those portions of the lower intestine containing pockets of gas.... The most common injuries to the viscera are rupture and bruising of intestinal walls, and bleeding from the blood vessels of the walls. Gut contents can escape into the peritoneal space if the intestinal wall is perforated.

"...(A)ir emboli produced by sublethal lung damage can lodge in the heart and brain, causing death by cardiac arrest or stroke.... (P)athological changes to the central nervous system [have been reported], but it is not clear whether these are caused by direct damage to the nervous system or are side-effects of injuries to the lungs or circulatory system. Extreme blast injury can involve the fracture of extremities and violent trauma to the thoracic cage and abdominal contents," (Hill, 1978).

"(L)arger animals are *less* subject to injury than small animals. This may be due to higher absorption of energy in the thicker body walls of larger animals. A rigid mass, either of bone or of an artificial nature, can afford some protection against shock waves. 'Rib markings' - areas of bruising and haemorrhage - have been

noted on the lungs of animals injured by underwater shock waves. These markings, indicating areas of greater damage, actually correspond to the spaces between the ribs, showing that the ribs protect the lungs beneath them.... (L)arge, uninflated lungs are less prone to be damaged by underwater shock waves than small, fully-inflated lungs," (Hill, 1978).

Figure 1 shows regression analyses of terrestrial animal test data from Yelverton (1981), as reported by BBN (1993). The curves shown in Figure 1 represent the best fit for "No Injury", "1% Mortality", and "50% Mortality" test data. These regression curves can be described by:

$$\ln I = 1.969 + 0.386 \ln M \quad \text{(No Injury)}$$

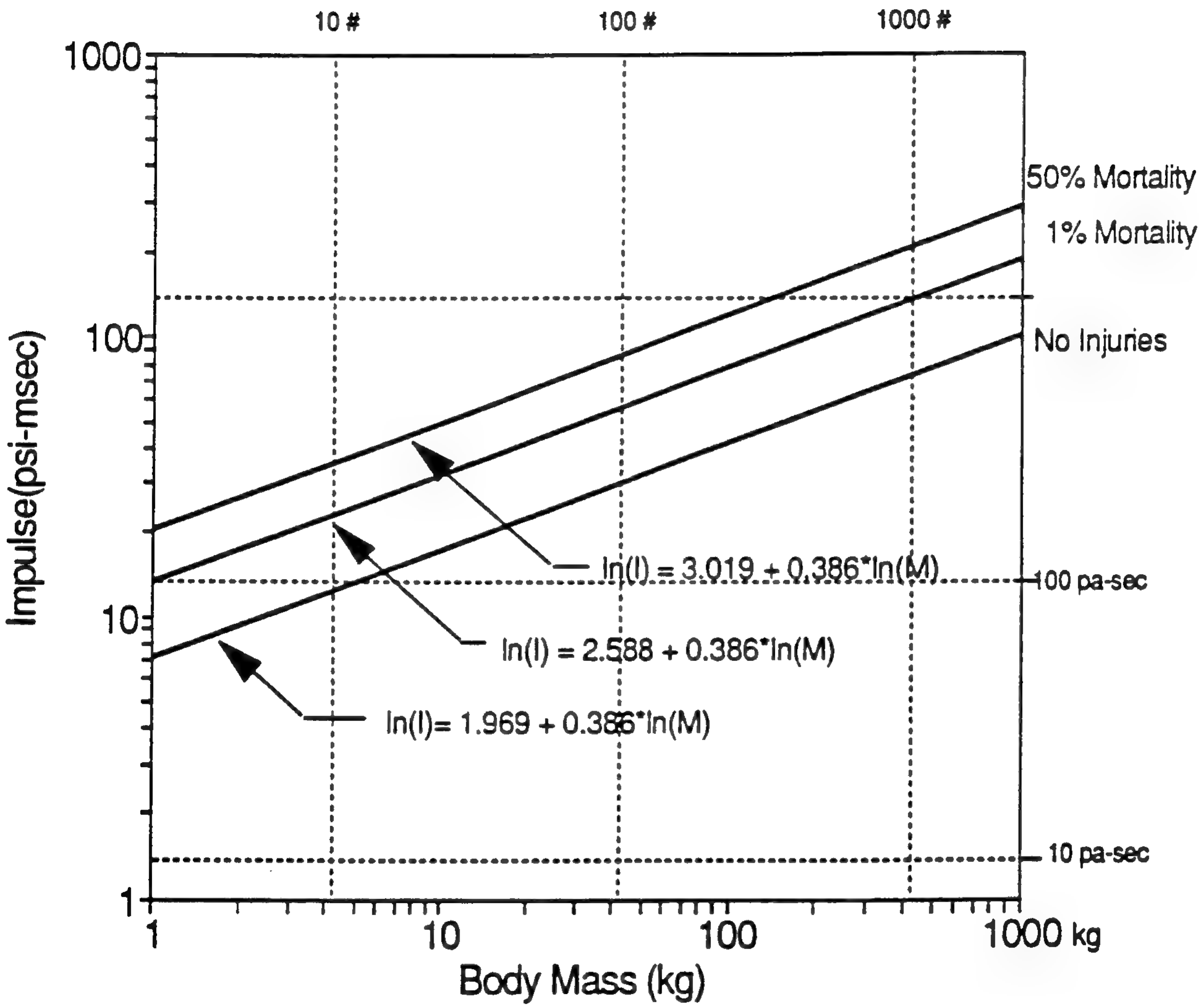
$$\ln I = 2.588 + 0.386 \ln M \quad \text{(1\% Mortality)}$$

$$\ln I = 3.019 + 0.386 \ln M \quad \text{(50\% Mortality)}$$

where I is impulse in psi-msec and M is body mass in kg.

B.1. <u>Onset of Slight Lung Injury</u>

Using data from the Yelverton, et al. (1973) report, Goertner (1982) developed a conservative computer model for the two primary injury mechanisms to mammals exposed to underwater explosion shockwaves. These mechanisms are: (1) lung hemorrhage, and (2) contusions of the G.I. tract. For lung hemorrhage, Goertner's model considers lung volume as a function of animal weight and depth and considers shockwave duration and impulse tolerance as a function of animal weight and depth.



Source: Yelverton (1981)

Figure 1. Regression Curves for Blast Damage to Mammals as a Function of Mammal Mass.

Injury to the G.I. tract was indexed to the ratio of peak shockwave pressure to the hydrostatic pressure at the mammal location. Injury to the G.I. tract is considered to be independent of mammal size and weight. G.I. tract injury is not specifically discussed in this section, since significant G.I. tract injury would generally be expected to occur at ranges less than the maximum ranges for the onset of slight lung injury.

Table 1 presents a comparison between actual small charge injury data (Richmond, et al., 1973) and predicted values based on the Goertner model. The reference values used in this application of the Goertner model are the lowest impulse and body mass for which slight lung injury was reported by Richmond, et al. (1973)--22.8 psi-msec (155.4 Pa-sec) and 93 lb (42 kg). After correcting for the atmospheric and hydrostatic pressures for the data, the minimum impulse for predicting onset of slight lung hemorrhage is:

$$I = 19.0\ (M/42)^{1/3}\ \text{psi-msec},$$

or

$$I = 129.5\ (M/42)^{1/3}\ \text{Pa-sec},$$

where M is the body mass (in kg) of the subject animal. The test data indicate the ranges, peak shockwave pressures and impulses for which slight lung hemorrhage

Table 1. Slight Lung Hemorrhage Model Verification.

EXPLOSIVE (Pentolite)		MAMMAL		TEST DATA[1]			MODEL PREDICTIONS[1]		
WEIGHT lb/(kg)	DEPTH ft/(m)	BODY MASS lb/(kg)	DEPTH ft/(m)	RANGE ft/(m)	PEAK PRESSURE psi/(kPa)	IMPULSE psi-msec/(Pa-sec)	RANGE ft/(m)	PEAK PRESSURE[1] psi/(kPa)	IMPULSE psi-msec/(Pa-sec)
1.052 (0.48)	10.0 (3.0)	108 (49)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	33 (10.1)	403 (2746)	20.2 (138)
1.052 (0.48)	10.0 (3.0)	101 (46)	1.0 (0.30)	16 (4.9)	987 (6726)	99.6 (679)	44 (13.4)	290 (1976)	19.9 (136)
1.052 (0.48)	10.0 (3.0)	75 (34)	1.0 (0.30)	26 (7.9)	588 (1007)	50.6 (345)	47 (14.3)	272 (1854)	18.0 (123)
1.052 (0.48)	10.0 (3.0)	35 (16)	1.0 (0.30)	26 (7.9)	588 (1007)	50.6 (345)	54 (16.5)	233 (1588)	14.0 (95)
1.052 (0.48)	10.0 (3.0)	44 (20)	1.0 (0.30)	26 (7.9)	478 (3257)	41.5 (283)	52 (15.9)	244 (1663)	15.1 (103)
1.052 (0.48)	10.0 (3.0)	13 (6)	1.0 (0.30)	26 (7.9)	478 (3257)	41.5 (283)	65 (19.8)	191 (1302)	10.1 (69)
1.052 (0.48)	10.0 (3.0)	82 (37)	2.0 (0.61)	33 (10.1)	436 (2971)	44.4 (303)	60 (18.3)	207 (1411)	18.9 (129)
1.052 (0.48)	10.0 (3.0)	90 (41)	2.0 (0.61)	33 (10.1)	436 (2971)	44.4 (303)	59 (17.9)	212 (1445)	19.5 (133)
1.052 (0.48)	10.0 (3.0)	93 (42)	10.0 (3.05)	48 (14.6)	269 (1833)	45.5 (310)	85 (25.9)	142 (968)	22.2 (151)
1.052 (0.48)	10.0 (3.0)	90 (41)	10.0 (3.05)	48 (14.6)	269 (1833)	45.5 (310)	86 (26.2)	141 (961)	22.0 (150)

Table 1. Slight Lung Hemorrhage Model Verification. (Continued)

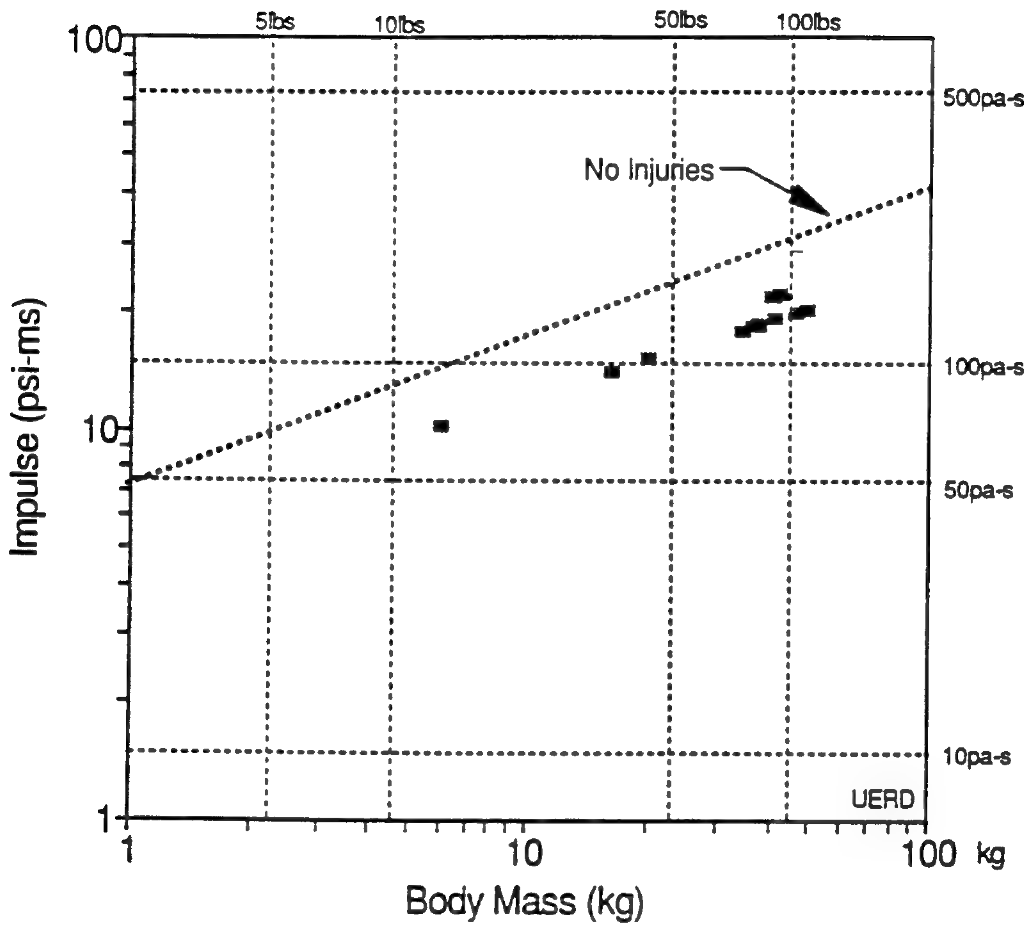
EXPLOSIVE (Pentolite)		MAMMAL		TEST DATA'			MODEL PREDICTIONS'		
WEIGHT lb/(kg)	DEPTH ft/(m)	BODY MASS lb/(kg)	DEPTH ft/(m)	RANGE ft/(m)	PEAK PRESSURE psi/(kPa)	IMPULSE psi-msec/(Pa-sec)	RANGE ft/(m)	PEAK PRESSURE[3] psi/(kPa)	IMPULSE psi-msec/(Pa-sec)
1.052 (0.48)	10.0 (3.0)	88 (40)	10.0 (3.05)	48 (14.6)	269 (1833)	45.5 (310)	86 (26.2)	139 (947)	21.8 (149)
1.052 (0.48)	10.0 (3.0)	93[1] (42)	10.0 (3.05)	84 (25.6)	153 (1043)	22.8[1] (155)	85 (25.9)	142 (968)	22.2 (151)
2.618 (1.19)	10.0 (3.0)	79 (36)	1.0 (0.30)	36 (11.0)	538 (3666)	40.3 (275)	58 (17.7)	304 (2072)	18.4 (125)
2.618 (1.19)	10.0 (3.0)	75 (34)	1.0 (0.30)	36 (11.0)	538 (3666)	40.3 (275)	58 (17.7)	301 (2051)	18.0 (123)
8.373 (3.80)	10.0 (3.0)	79 (36)	1.0 (0.30)	52 (15.8)	556 (3789)	33.2 (226)	73 (22.3)	357 (2433)	18.4 (125)
8.373 (3.80)	10.0 (3.0)	82 (37)	1.0 (0.30)	52 (15.8)	556 (3789)	33.2 (226)	73 (22.3)	359 (2447)	18.5 (126)
8.373 (3.80)	10.0 (3.0)	79 (36)	1.0 (0.30)	52 (15.8)	556 (3789)	33.2 (226)	73 (22.3)	357 (2433)	18.4 (125)

1 Occurrence of Slight Lung Hemorrhage (Richmond, et al., 1973)
2 Onset of Slight Lung Hemorrhage (after Goertner, 1982)
3 Weak Shock Theory (Gaspin, 1983)
4 Reference value for calculations

Source: CD-NSWC/UERD

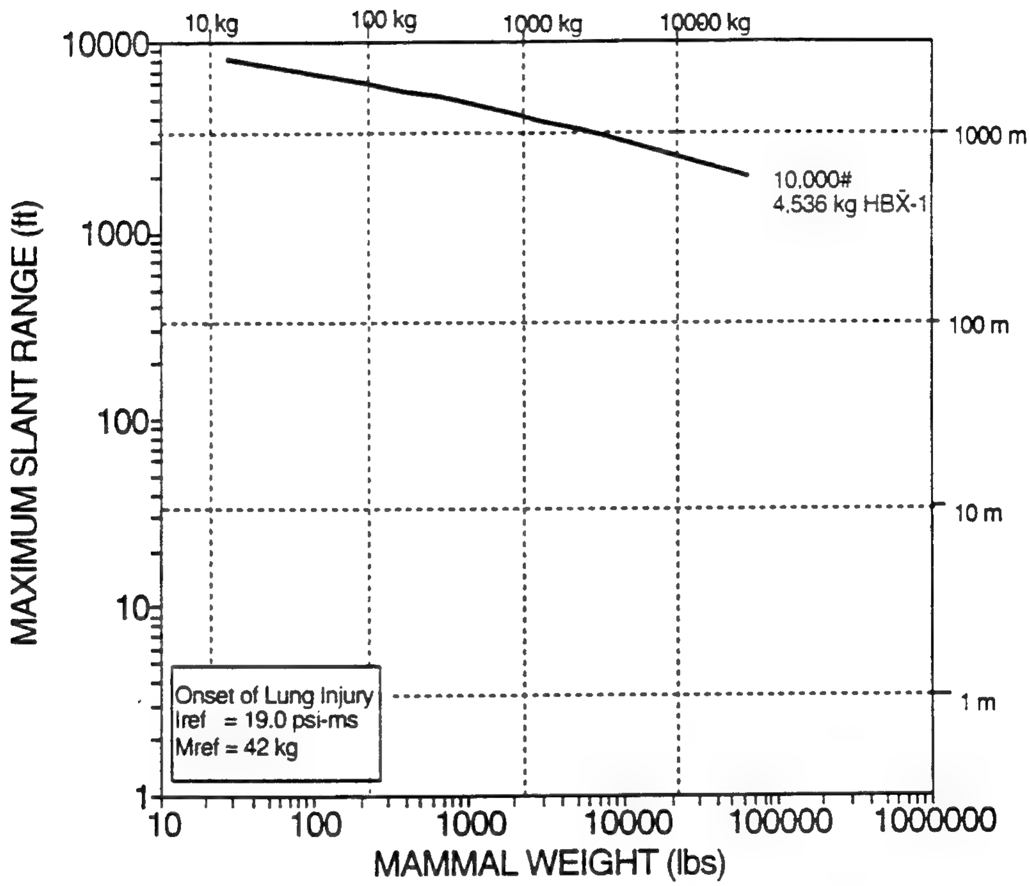
actually occurred to the test subject. The model predictions are ranges, peak pressures, and impulses which should describe conditions sufficient for the onset of slight lung hemorrhage. Regression curve values (Yelverton, 1981) indicate that for the range of body weights (masses) of 13 to 93-lb (6 to 42-kg), the "No Injury" impulses would be expected to range from 14.3 to 30.3 psi-msec (98 to 207 Pa-sec). Predictions for onset of slight lung injury based on actual test conditions using the Goertner model indexed to 19 psi-msec (130 Pa-sec) for a 93-lb (42-kg) mammal range from 10.1 to 22.2 psi-msec (69 to 151 Pa-sec). Figure 2 presents a comparison between the Yelverton (1981) "No Injury" regression curve for impulse vs. body mass and a plot of the predicted impulses for onset of slight lung hemorrhage for the test conditions in Table 1. In order for the onset of slight lung injury model to be conservative, the predicted impulse values must be no greater than either the test values or regression curve predictions and the predicted ranges must be no less than the test values. As can be seen in Table 1 and Figure 2, these conditions are met by the onset of slight lung injury model.

Figure 3 shows maximum calculated slant ranges for the onset of slight lung hemorrhage as a function of mammal weight for a 10,000-lb (4536-kg) charge. Slight lung hemorrhage is an injury from which a mammal would be expected to recover on its own and would not be debilitating. Charge and mammal depths have been varied so that the values shown in Figure 3 are conservative for any depths.



Source: Yelverton (1981), CD-NSWC/UERD

Figure 2. Comparison of Impulses for No-Injury and for Onset of Slight Lung Hemorrhage.



Source: CD-NSWC/UERD after Goertner (1982)

Figure 3. Calculated Ranges for Onset of Slight Lung Hemorrhage as a Function of Mammal Weight for a 10,000-lb (4536-kg) Charge.

Safety ranges for the shock test should be chosen conservatively to preclude injury (including eardrum rupture) to mammals of this size. The nominal calculated range for onset of slight lung hemorrhage for a 220-lb (100-kg) mammal from a 10,000-lb (4536-kg) charge (the charge to be used in the shock test) yields a maximum slant range of 6069 ft (1850 m) for the onset of slight lung hemorrhage.

B.2. Lethal Injury

B.2.1. Lethality from Injury to Internal Organs

"The major cause of immediate death due to underwater shock waves is suffocation caused by extensive haemorrhaging into the lungs. Air emboli can cause death soon after sublethal lung injury. In addition, fatal circulatory failure can occur, probably as a result of the obstruction of pulmonary circulation due to lung damage combined with general system shock. Death often occurs at some considerable time after the original injury. This usually comes about as a result of complications, such as broncho-pneumonia in damaged lungs, or peritonitis resulting from perforations of the intestinal wall," (Hill, 1978).

Richmond, et al. (1973) reported that the lowest impulse level to inflict extensive lung injury was 44.4 psi-msec (302.6 Pa-sec) for a 75-lb (34-kg) mammal. After correcting for atmospheric and hydrostatic pressures, and based on the cube root

scaling of body mass as used in the Goertner lung injury model, the minimum impulse for predicting onset of extensive lung hemorrhage is:

$$I_{1\%} = 42.0\ (M/34)^{1/3}\ \text{psi-msec}$$

or

$$I_{1\%} = 286.2\ (M/34)^{1/3}\ \text{Pa-sec},$$

where M is the body mass (in kg) of the subject animal and $I_{1\%}$ is the minimum impulse for 1% mortality. For a 93-lb (42-kg) animal, the predicted impulse for onset of extensive lung hemorrhage would be 45.1 psi-msec (307.4 Pa-sec). (From Section B.1, the minimum impulse level for predicting slight lung hemorrhage for the same 93-lb [42-kg] animal is 19.0 psi-msec [129.5 Pa-sec]). Although the Goertner model was not originally developed for mortality calculations, it lends itself to this use because of the ability to specify reference impulse and body mass values.

Table 2 provides a comparison between actual injury data (Richmond, et al., 1973), the Yelverton (1981) 1% Mortality regression curve, and predicted values based on the Goertner model as utilized in this document. The test data indicate ranges, peak shockwave pressures and impulses for which extensive lung hemorrhage actually occurred to the test subjects. The model predictions are ranges, peak pressures, and impulses which should describe conditions sufficient for the onset of extensive lung hemorrhage when using the modified Goertner model.

Table 2. Onset of Extensive Lung Hemorrhage (1% Mortality) Model Verification.

EXPLOSIVE (Pentolite)		MAMMAL		TEST DATA[1]			MODEL PREDICTIONS[2]		
WEIGHT lb/(kg)	DEPTH ft/(m)	BODY MASS lb/(kg)	DEPTH ft/(m)	RANGE ft/(m)	PEAK PRESSURE psi/(kPa)	IMPULSE psi-msec/ (Pa-sec)	RANGE ft/(m)	PEAK PRESSURE[3] psi/(kPa)	IMPULSE psi-msec/ (Pa-sec)
1.052 (0.48)	10.0 (3.0)	95 (43)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	21 (6.4)	684 (4661)	45.8 (312)
1.052 (0.48)	10.0 (3.0)	106 (48)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	20 (6.1)	702 (4784)	47.5 (324)
1.052 (0.48)	10.0 (3.0)	110 (50)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	20 (6.1)	708 (4825)	48.2 (328)
1.052 (0.48)	10.0 (3.0)	108 (49)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	20 (6.1)	705 (4805)	47.9 (326)
1.052 (0.48)	10.0 (3.0)	95 (43)	1.0 (0.30)	16 (4.9)	987 (6726)	99.6 (679)	26 (7.9)	522 (3557)	46.2 (315)
1.052 (0.48)	10.0 (3.0)	99 (45)	1.0 (0.30)	16 (4.9)	987 (6726)	99.6 (679)	26 (7.9)	528 (3598)	46.9 (320)
1.052 (0.48)	10.0 (3.0)	75[4] (34)	2.0 (0.61)	33 (10.1)	436 (2971)	44.4[4] (303)	34 (10.4)	394 (2685)	43.5 (296)

[1] Occurrence of Extensive Lung Hemorrhage (Richmond, et al., 1973)
[2] Onset of Extensive Lung Hemorrhage (after Goertner, 1982)
[3] Weak Shock Theory (Gaspin, 1983)
[4] Reference value for calculations

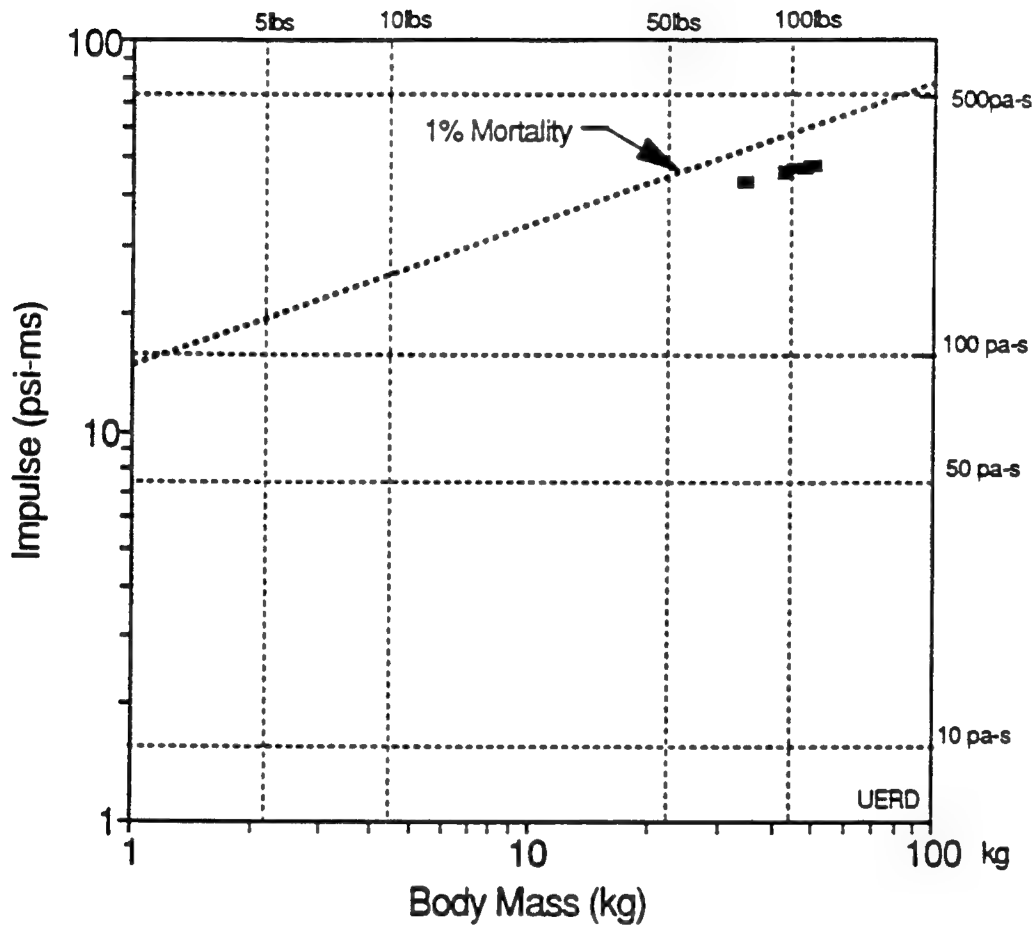
Source: CD-NSWC/UERD

Regression curve values (Yelverton, 1981) indicate that for the range of body weights (masses) of 75 to 110-lb (34 to 50-kg) the "1% Mortality" impulses would be expected to range from 51.9 to 60.2 psi-msec (354 to 410 Pa-sec). Predictions for onset of extensive lung hemorrhage based on actual test conditions using the Goertner model indexed to 42 psi-msec (286.2 Pa-sec) for a 75-lb (34-kg) mammal range from 43.5 to 48.2 psi-msec (296 to 328 Pa-sec).

Figure 4 presents a comparison between the impulses based on the Yelverton (1981) 1% Mortality regression curve and the model predictions from Table 2. In order for the onset of extensive lung injury model to be conservative, the predicted impulse values must be no greater than either the test values or the regression curve values, and the predicted ranges must be no less than the test values.

As can be seen in Table 2 and Figure 4, these conditions are met by the onset of extensive lung injury model. The predicted onset of extensive lung hemorrhage can be used as a conservative index for onset of mortality (1%). (Because of the possible extreme combinations of very small charges and large to extremely large mammals, the onset of extensive lung injury model would not always apply. The extreme short ranges and resultant high peak shockwave pressures become indicative of external tissue damage and associated injuries.[3] The onset of extensive lung injury model is

[3] External tissue damage to marine mammals is discussed in Section B.2.2.



Source: Yelverton (1981), CD-NSWC/UERD

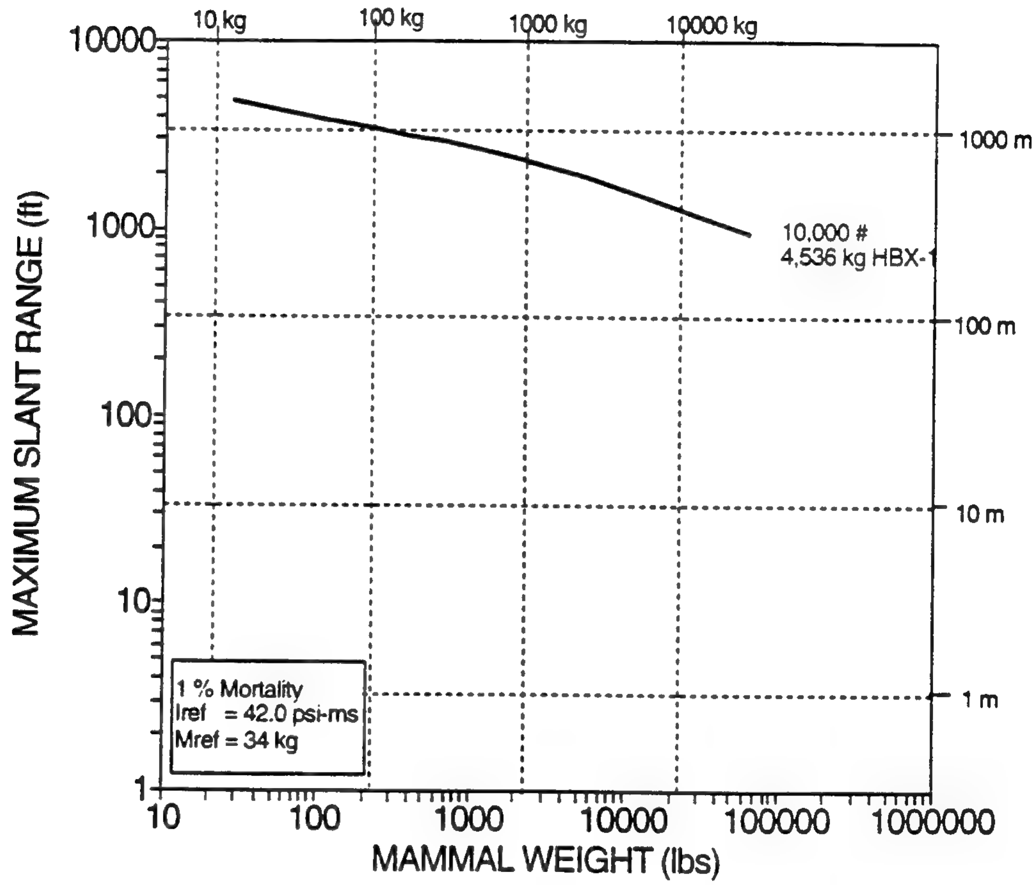
Figure 4. Comparison of Predicted 1% Mortality and Calculated Onset of Extensive Lung Hemorrhage Impulses.

therefore limited to ranges and impulses where the peak shockwave pressure is less than 1400 psi [9.7 MPa]).

Figure 5 presents maximum calculated slant ranges for the onset of extensive lung hemorrhage as a function of mammal weight for the 10,000-lb (4536-kg) charge. Charge and mammal depths have been varied so that the ranges shown in Figure 5 are conservative for any depths. Extensive lung hemorrhage is an injury which would be debilitating and not all animals would be expected to survive (1% mortality).

Based on pathology reports (Richmond, et. al., 1973), G.I. tract injuries associated with the onset of extensive lung hemorrhage would include contusions with no ulcerations. As the severity of extensive lung hemorrhage increases beyond the onset level, G.I. tract injuries can increase significantly to include contusions with ulcerations throughout the entire G.I. tract and ultimately to include ruptures of the G.I. tract. The expected mortality level associated with these combined severe injuries would be significantly higher than 1%.

Based on the Yelverton (1981) 50% Mortality regression curve, impulses sufficient for 50% mortality range from 79.9 to 92.7 psi-msec (545 to 632 Pa-sec) for the range of body weights (masses) of 75 to 110-lb (34 to 50-kg). Referring to Table 2 it can be seen that the first six rows of test data have values near or within the



Source: CD-NSWC/UERD

Figure 5. Maximum Calculated Ranges for 1% Mortality (Onset of Extensive Lung Hemorrhage) as a Function of Mammal Weight for a 10,000-lb (4536-kg) Charge.

Yelverton 50% Mortality requirements. Table 3 presents a comparison of test data (Richmond, et al., 1973) and Goertner model predictions. For occurrence of extensive lung hemorrhage, the Goertner model was indexed to 83.4 psi-msec (568.4 Pa-sec) for a 95-lb (43-kg) mammal, or:

$$I_{50\%} = 83.4\ (M/43)^{1/3}\ \text{psi-msec}$$

and

$$I_{50\%} = 568.4\ (M/43)^{1/3}\ \text{Pa-sec},$$

where M is the body mass (in kg) of the subject animal and $I_{50\%}$ is impulse for 50% mortality.

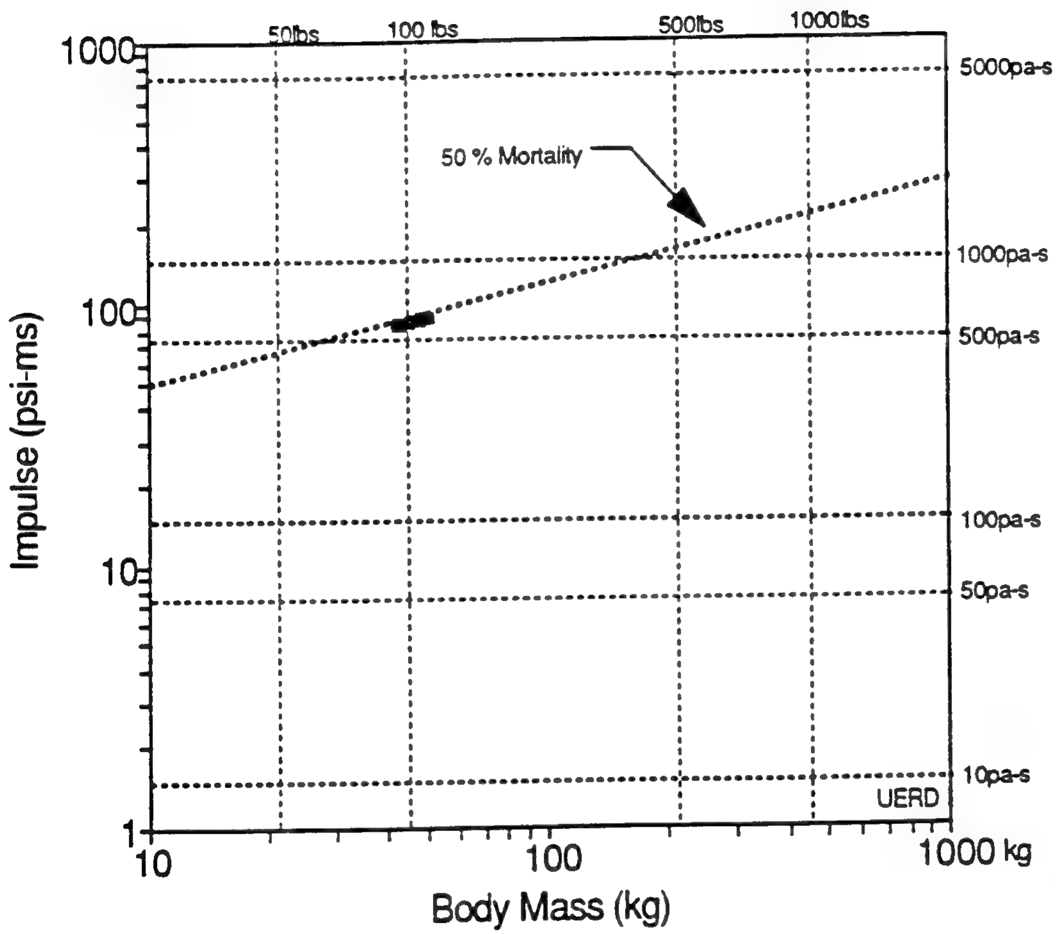
Figure 6 presents a comparison between the impulses based on the Yelverton (1981) 50% Mortality curve and the model predictions from Table 3. The extensive lung hemorrhage calculations are in good agreement with the test data and the Yelverton 50% Mortality regression curve. The predicted impulse values are less than the regression curve values and the predicted ranges are slightly greater than the test values. The range and impulse values predicted for the occurrence of extensive lung hemorrhage and its attendant severe to extensive G.I. tract injuries can be used as an index for 50% mortality.

Table 3. Extensive Lung Hemorrhage (50% Mortality) Model Verification.

EXPLOSIVE (Pentolite)		MAMMAL		TEST DATA[1]			MODEL PREDICTIONS[2]		
WEIGHT lb/(kg)	DEPTH ft/(m)	BODY MASS lb/(kg)	DEPTH ft/(m)	RANGE ft/(m)	PEAK PRESSURE psi/(kPa)	IMPULSE psi-msec/ (Pa-sec)	RANGE ft/(m)	PEAK PRESSURE[3] psi/(kPa)	IMPULSE psi-msec/ (Pa-sec)
1.052 (0.48)	10.0 (3.0)	95 (43)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	14 (4.3)	1072 (7306)	84.1 (573)
1.052 (0.48)	10.0 (3.0)	106 (48)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	14 (4.3)	1105 (7531)	87.3 (595)
1.052 (0.48)	10.0 (3.0)	110 (50)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	14 (4.3)	1117 (7612)	88.5 (603)
1.052 (0.48)	10.0 (3.0)	108 (49)	0.5 (0.15)	13 (4.0)	1089 (7422)	85.7 (584)	14 (4.3)	1111 (7571)	87.9 (599)
1.052 (0.48)	10.0 (3.0)	95 (43)	1.0 (0.30)	16 (4.9)	987 (6726)	99.6 (679)	17 (5.2)	875 (5963)	84.9 (579)
1.052 (0.48)	10.0 (3.0)	99 (45)	1.0 (0.30)	16 (4.9)	987 (6726)	99.6 (679)	17 (5.2)	887 (6045)	86.2 (587)

1 Occurrence of Extensive Lung Hemorrhage (Richmond, et al., 1973)
2 Extensive Lung Hemorrhage (after Goertner, 1982)
3 Weak Shock Theory (Gaspin, 1983)

Source: CD-NSWC/UERD



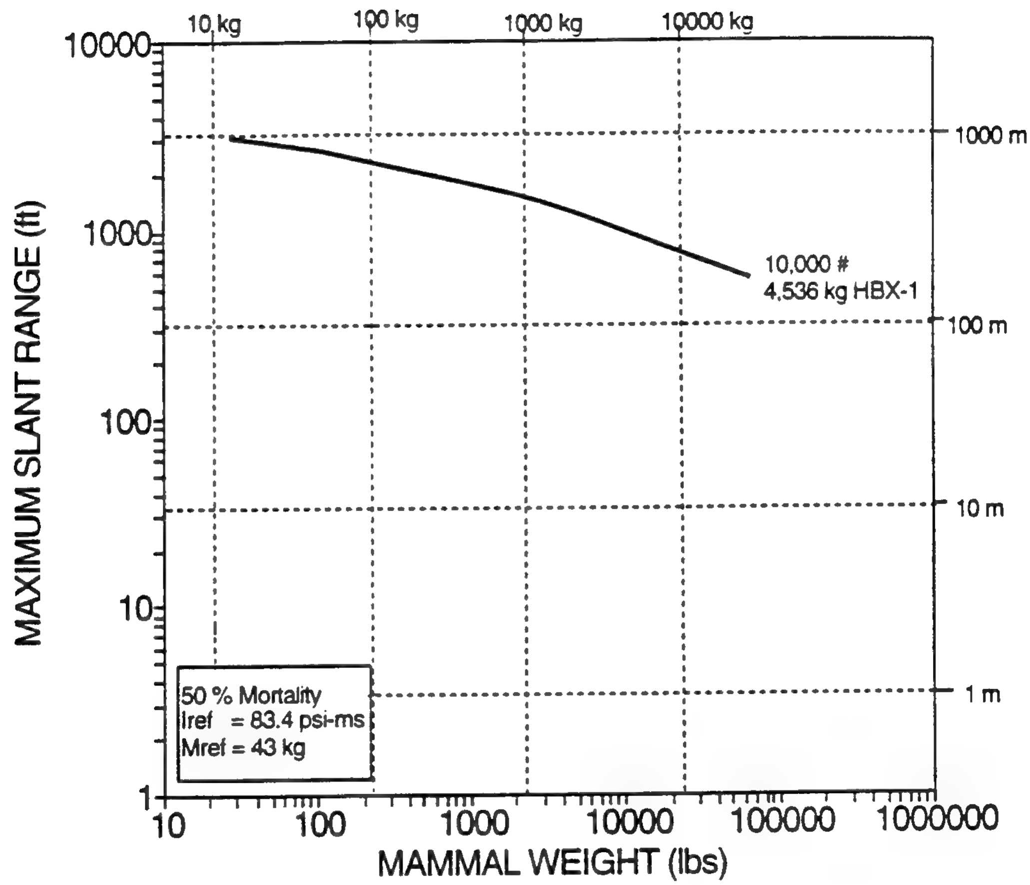
Source: Yelverton (1981), CD-NSWC/UERD

Figure 6. Comparison of Predicted 50% Mortality and Calculated Extensive Lung Hemorrhage Impulses.

Figure 7 presents maximum calculated slant ranges for the occurrence of 50% mortality (extensive lung hemorrhage) as a function of mammal weight for a 10,000-lb (4536-kg) charge. Charge and mammal depths have been varied so that the ranges shown in Figure 7 are conservative for any depths. (As with the onset of extensive lung injury model, the extensive lung injury model is limited to ranges and impulses where the peak shockwave pressure is less than 1400 psi [9.7 MPa].)

B.2.2. Lethal Injury from Shockwaves with High Peak Pressure

Myrick, et al. (1990) reported on the effects to dolphin carcasses from underwater explosion tests using a 0.15 oz (5.76 gm) "seal bomb". No damage was noted at a detonation distance of 2.3 ft (0.7 m). When the "seal bomb" was detonated 2 ft (0.6 m) away, "... a 5 x 7-cm jagged wound 4-cm deep was incurred above the right shoulder.... Subsequent examination of the carcass disclosed that the right shoulder blade had been shattered, the diaphysis of the humerus fractured, and the subscapular and intercostal musculature pulverized, but no penetration was made into the pulmonary cavity. Examination of the cranial bones revealed fractures to hamular processes of both pterygoids and a fractured left temporal bone. No internal damage was found, except possible evidence of compression on the right lung by the first right rib, thought perhaps to have been associated with the shoulder-blast damage. Participants in the examination of the specimen could not attribute cause of the cranial damage to test explosions partly because the



Source: CD-NSWC/UERD

Figure 7. Maximum Calculated Ranges for 50% Mortality (Extensive Lung Hemorrhage) as a Function of Mammal Weight for a 10,000-lb (4536-kg) Charge.

temporal fracture was on the side opposite the shoulder damage. Further, there was no certainty that the cranial damage was not incurred elsewhere since postmortem history of the specimen was unknown," (Myrick, et al., 1990).

Assuming the "seal bomb" to have a 90% TNT equivalence, the calculated peak shockwave pressures are 1451 psi (10.0 MPa) at a distance of 2.3 ft (0.7 m), and 1711 psi (11.8 MPa) at a distance of 2 ft (0.6 m). Animals exposed to shockwave pressures of these magnitudes, regardless of the charge size or animal body weight, will be subjected to extremely high impulse levels. Depending upon the size of the animal, these impulse levels may or may not be lethally injurious to the animals' internal organs; however, shock and significant external tissue damage as well as possible damage to the skeletal system would be expected. Animals suffering these types of injuries would also likely be at increased risk of disease and predation. All internal organ injury models utilized in this document use the 1400 psi (9.7 MPa) peak shockwave pressure as a limiting value. Animals exposed to peak shockwave pressures in excess of 1400 psi (9.7 MPa) would be considered lethally injured.

B.3. Auditory System Injury

Eardrum damage criteria are based on a limited number of small charge tests as reported by both Yelverton, et al. (1973) and Richmond, et al. (1973). Eardrum-specific tests were conducted with dogs using nominal 1-lb (0.45-kg) TNT

charges. Additional eardrum data from general injury tests conducted with sheep using nominal 0.5-lb and 1-lb (0.23-kg and 0.45-kg) pentolite charges are also included in order to develop a conservative eardrum damage model. The test conditions and results from Richmond, et al. (1973) are provided in Table 4. Since the purpose of developing an eardrum damage model is to conservatively predict damage (percent rupture) based on actual data, the model development will be based on actual test geometries, actual minimum charge weights, and worst case results. The model will utilize calculated shockwave parameters to tie in test data to computations. Seven of the eleven test groups were conducted with only three subjects; two with six subjects; and two with twelve subjects. In some instances, eardrums were not accessible or readable following a test. These cases are counted as possible ruptures for the eardrum damage model development. To simplify the analysis, only eardrums directly facing the blast are used. Eardrums facing away from the blast were potentially subjected to significantly different shockwave loading than those directly facing the blast. Additionally, eardrums facing away from the blast may have been damaged by later-occurring intra-cranial pressures and/or cranial trauma rather than by directly measurable or readily calculable shockwave parameters. Handling and submergence tests conducted with control animals not subjected to explosions did not cause any eardrum ruptures.

Table 4. Eardrum Damage Test Conditions and Results.

DATA SET	EXPLOSIVE[1]		RANGE	PEAK PRESSURE[2]	TOTAL IMPULSE[2]	TOTAL ENERGY[2]	EARDRUMS[3]		NO. RUPTURED	% RUPTURED
	Type	Weight lb / (kg)	ft / (m)	psi / (kPa)	psi-msec / (Pa-sec)	in-lb/in² / (milli-Joules/cm²)	No.	depth ft / (m)		
1	TNT	1.047 (0.47)	20 (6.1)	672 (4580)	59.4 (405)	4.244 (74.34)	3	1 (0.3)	3	100
2	TNT	1.047 (0.47)	40 (12.2)	306 (2085)	21.2 (144)	0.854 (14.96)	12	1 (0.3)	4 - 5[4]	33 - 42[4]
3	TNT	1.047 (0.47)	45 (13.7)	269 (1833)	17.3 (118)	0.637 (11.16)	6	1 (0.3)	0	0
4	TNT	1.047 (0.47)	60 (18.3)	195 (1329)	10.5 (71)	0.301 (5.27)	3	1 (0.3)	0	0
5	PENTOLITE	1.047 (0.47)	33 (10.1)	401 (2733)	44.4 (303)	1.912 (33.49)	3	2 (0.6)	2	67
6	PENTOLITE	1.047 (0.47)	54 (16.5)	232 (1581)	22.2 (151)	0.653 (11.44)	3	2 (0.6)	0	0
7	PENTOLITE	1.047 (0.47)	83 (253)	145 (988)	10.9 (74)	0.228 (3.99)	3	2 (0.6)	0	0
8	PENTOLITE	1.047 (0.47)	48 (14.6)	264 (1799)	37.4 (255)	0.931 (16.31)	3	10 (3.0)	0	0
9	PENTOLITE	1.047 (0.47)	84 (25.6)	143 (975)	22.3 (152)	0.313 (5.48)	6	10 (3.0)	0 - 1[4]	0 - 17[4]
10	PENTOLITE	0.485 (0.22)	93 (28.3)	97 (661)	6.9 (47)	0.093 (1.63)	3	2 (0.6)	0	0
11	PENTOLITE	0.485 (0.22)	100 (30.5)	89 (607)	12.0 (82)	0.106 (1.86)	12	10 (3.0)	1	8

1 Minimum charge weights; all tests conducted with charge at 10 ft (3.0 m) depth.
2 Calculated values.
3 Eardrums facing the charge.
4 Not all eardrums were accessible or readable following a test; the second value given presumes that these eardrums were ruptured.

Source: Richmond, et al. (1973); CD-NSWC/UERD

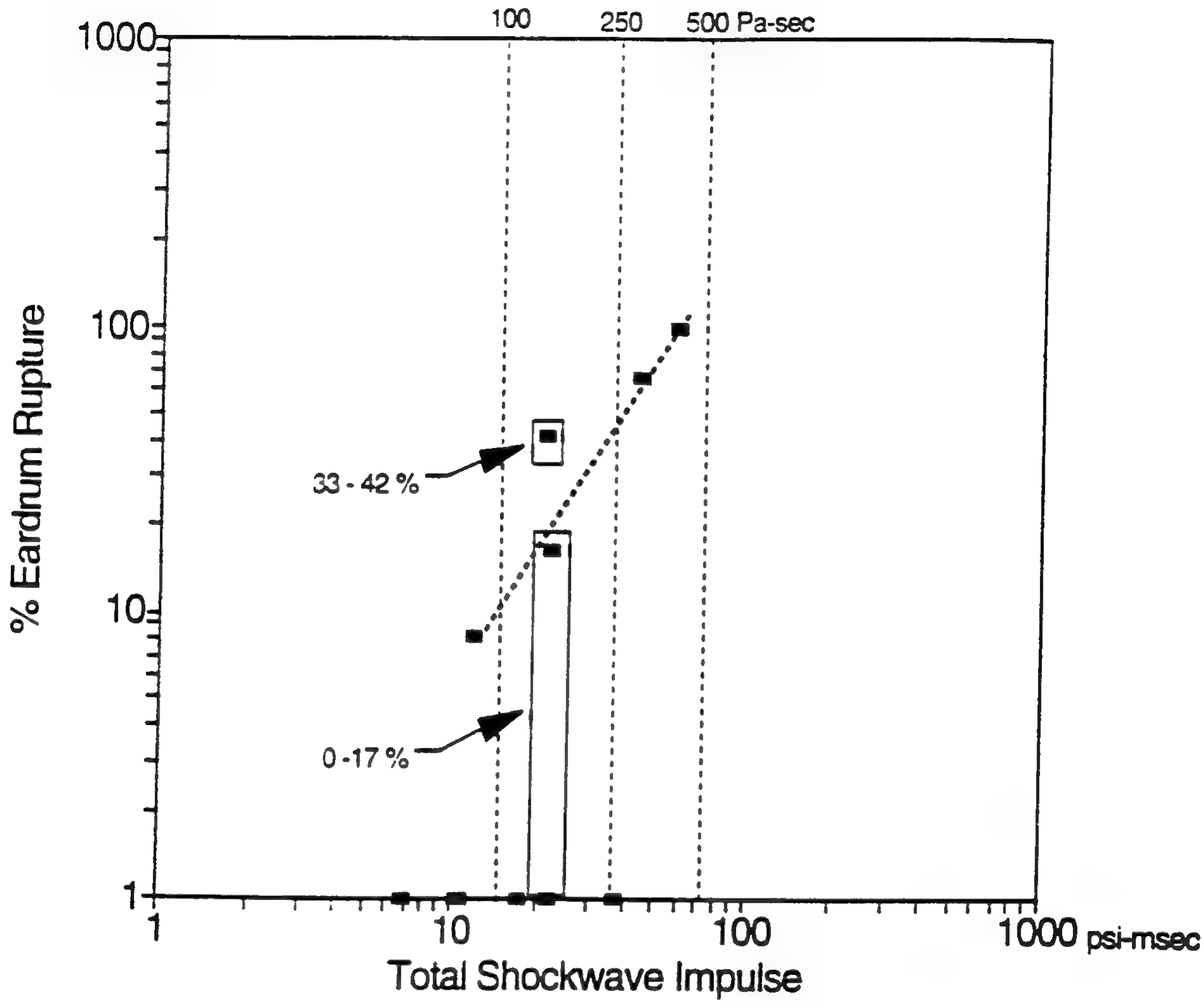
Damage to mammal organs has typically been referenced to total shockwave impulse--both Richmond, et al. (1973) and Yelverton, et al. (1973) referenced eardrum rupture to total shockwave impulse. Figure 8 shows percentage of eardrum ruptures as a function of calculated total shockwave impulse using data sets 1, 2, 5, 9, and 11 from Table 4. It can be seen that total shockwave impulse is a general indicator of the possibility of eardrum rupture.

Figure 9 is percent eardrum rupture as a function of calculated total shockwave energy using the calculated values from Table 4. The upper bound for percentages of eardrums ruptured and the computed energy values from data sets 2, 5, 9, and 11 fall reasonably into place along an exponential curve. Data set 1 was excluded since the energy value may well have been in excess of the minimum energy required for 100% rupture.

Using data sets 5 and 11, the exponential curve in Figure 9 can be conservatively expressed as:

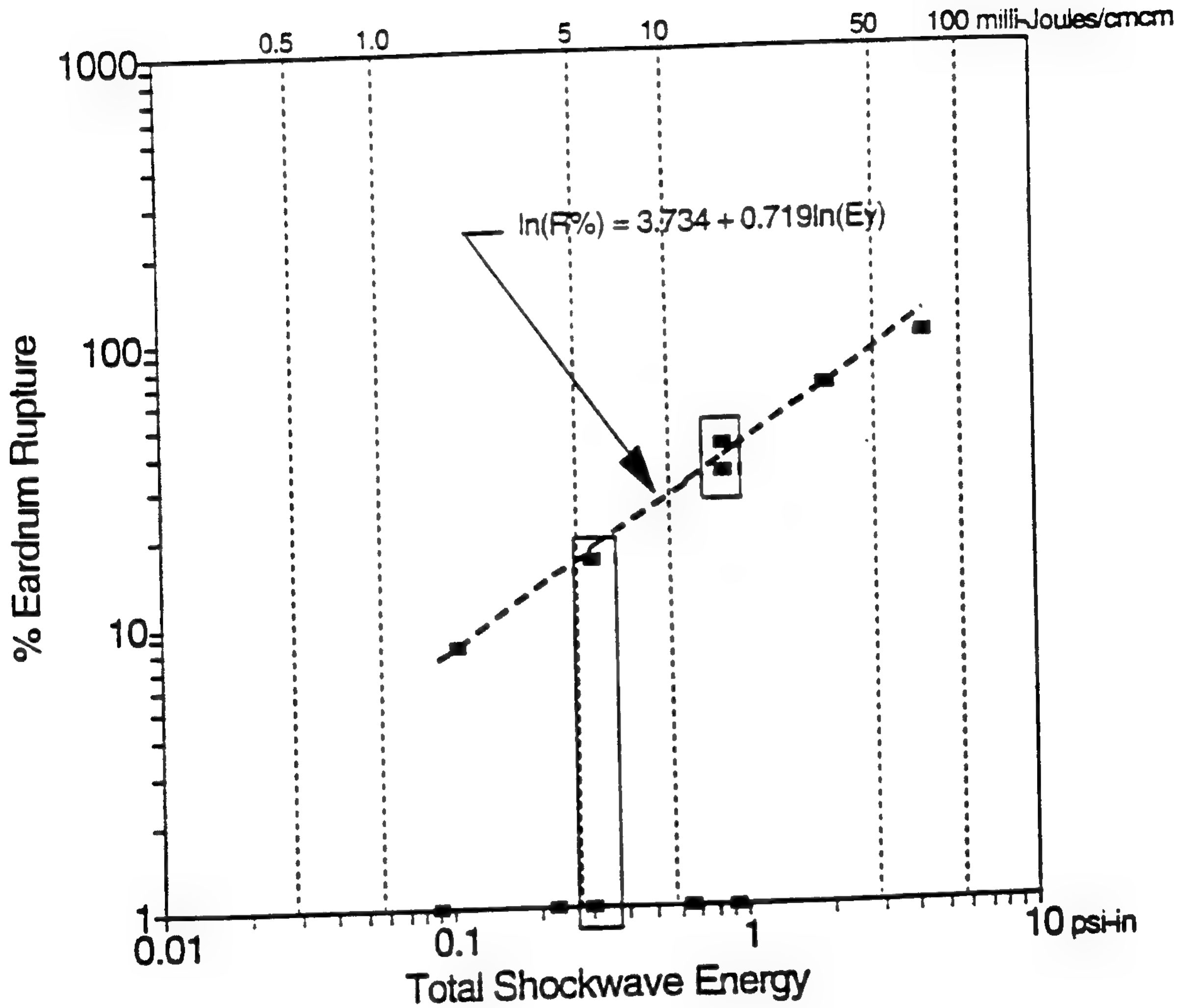
$$\ln R_{\%} = 3.734 + 0.719 \ln E, \qquad (1)$$

where $R_{\%}$ is the maximum percentage of eardrums ruptured and E is the calculated total shockwave energy (in in-lb/in^2). For nominal 0.5-lb to 1-lb (0.23-kg to 0.45-kg) charges at very shallow depths, equation (1) should be more than adequate to



Source: CD-NSWC/UERD after Richmond, et al. (1973) and Yelverton, et al. (1973)

Figure 8. Eardrum Rupture as a Function of Calculated Total Shockwave Impulse.



Source: CD-NSWC/UERD

Figure 9. Eardrum Rupture as a Function of Calculated Total Shockwave Energy.

accurately predict percentages of rupture and/or standoffs for a given rupture percentage. Equation (1) would not be expected to accurately predict eardrum ruptures from larger and/or deeper charges that have shockwaves with significantly larger decay constants and/or longer durations when compared with the test data.

Table 5 provides calculated shockwave pressures and incremental energies for data sets 1, 2, 5, 9, and 11 in 0.10 msec increments from shockwave arrival to surface cut-off time. Using data sets 5, 9, and 11 from Table 5, an iterated numerical solution can be achieved for the percentage of eardrums ruptured as a function of incremental shockwave energy. The equations to be solved have the form:

$$a(1.00) + b(1.00-a) + c[(1.00-a)-b(1.00-a)] + d\{(1.00-a)-b(1.00-a)-c[(1.00-a)-b(1.00-a)]\} + \ldots = R_{\%}/100,$$

where a, b, c, d are percentages (divided by 100) of eardrums ruptured at 0.10, 0.20, 0.30, 0.40 msec, respectively, and $R_{\%}$ is the total percentage of eardrums ruptured for the total composite shockwave. The iterated approximate numerical solutions for data sets 5, 9, and 11 are provided in Table 6 and plotted in Figure 10.

The exponential curve from Figure 10 can be conservatively described by:

$$\ln R_{\%} = 3.778 + 0.767 \ln E_i \,, \tag{2}$$

Table 5. Calculated Shockwave Pressures and Incremental Energies.

DATA SET*	TIME (msec)	PRESSURE psi	(kPa)	INCREMENTAL ENERGY in-lb/in²	(milli-Joules/cm²)	RUPTURES (%)
1	0.000	672	(4580)	0.000	--	100.0
	0.100	252	(1717)	3.712	(65.02)	
	0.200	95	(647)	0.522	(9.14)	
	0.206	89	(606)	0.010	(0.18)	
2	0.000	306	(2085)	0.000	--	33.3-41.6
	0.100	129	(879)	0.839	(14.69)	
	0.105	124	(845)	0.014	(0.25)	
5	0.000	401	(2733)	0.000	--	66.7
	0.100	185	(1261)	1.538	(26.94)	
	0.200	85	(579)	0.326	(5.71)	
	0.251	57	(388)	0.048	(0.84)	
9	0.000	143	(975)	0.000	--	0-16.7
	0.100	78	(532)	0.221	(3.87)	
	0.200	42	(286)	0.065	(1.14)	
	0.300	23	(157)	0.020	(0.35)	
	0.400	13	(89)	0.005	(0.09)	
	0.494	7	(48)	0.002	(0.04)	
11	0.000	89	(607)	0.000	--	8.3
	0.100	44	(300)	0.080	(1.40)	
	0.200	22	(150)	0.020	(0.35)	
	0.300	11	(75)	0.005	(0.09)	
	0.400	5	(34)	0.001	(0.02)	
	0.417	5	(34)	0.000	(0)	

*From Table 4

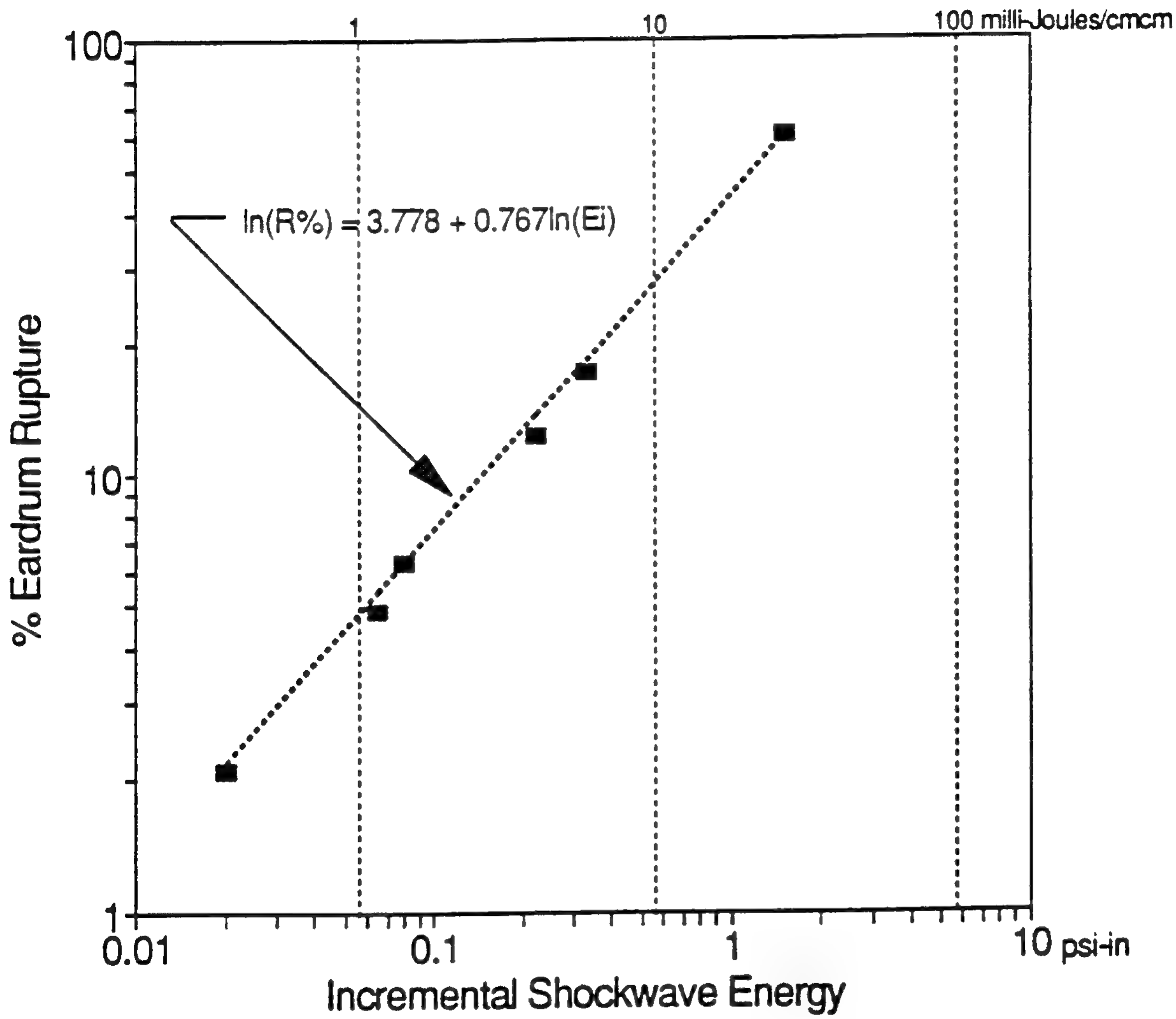
Source: CD-NSWC/UERD

Table 6. Calculated Percentage of Eardrum Ruptures for Discrete Values of Calculated Shockwave Energy.

INCREMENTAL ENERGY, E in-lb/in^2	(milli-Joules/cm^2)	DATA SET[1]	RUPTURE PERCENTAGE
0.020	(0.35)	9, 11	2.1
0.065	(1.14)	9	4.9
0.080	(1.40)	11	6.3
0.221	(3.87)	9	12.4
0.326	(5.71)	5	17.5
1.538	(26.93)	5	60.8

[1] From Table 4

where $R_{\%}$ is the incremental rupture percentage and E_i is the incremental shockwave energy. Equation (2) is used by breaking down a shockwave into 0.10 msec increments and computing a rupture percentage--the computed percentage must be applied to the remaining unruptured percentage from all previous iterations. For shockwave increments less than 0.10 msec duration, the computed percentage is multiplied by the ratio of the actual duration to the 0.10 msec increment basis. Table 7 presents the actual and computed rupture percentages and the actual and computed number of ruptures for data sets 1 through 11 using equations (1) and (2). Computations using equation (2) were terminated at surface cutoff time, or when the calculated shockwave pressure dropped below 20 psi (136.3 kPa). As shown in Table 7, predicted eardrum ruptures using either equation (1) or (2) compare very well with the test data. Although there are no large charge data available to verify the



Source: CD-NSWC/UERD

Figure 10. Eardrum Rupture as a Function of Incremental Shockwave Energy.

Table 7. Comparison of Actual and Predicted Terrestrial Mammal Eardrum Ruptures.

DATA SET[1]	SAMPLE SIZE	ACTUAL		PREDICTED[2]		PREDICTED[3]	
		%	NO. OF RUPTURES	%	NO. OF RUPTURES	%	NO. OF RUPTURES
1	3	100	3	100	3	100	3
2	12	33 - 42	4 - 5	37	4	38	5
3	6	0	0	30	2	29	2
4	3	0	0	18	1	12	0
5	3	67	2	67	2	69	2
6	3	0	0	31	1	31	1
7	3	0	0	14	0	7	0
8	3	0	0	40	1	44	1
9	6	0 - 17	0 - 1	18	1	21	1
10	3	0	0	9	0	6	0
11	12	8	1	8	1	9	1

[1] From Table 4
[2] Using equation (1)
[3] Using equation (2)

applicability of either equation to large charge tests, equation (2) should be used as a conservative predictive tool for estimating eardrum ruptures for charge weights and charge depths that are outside the range of the original test data.

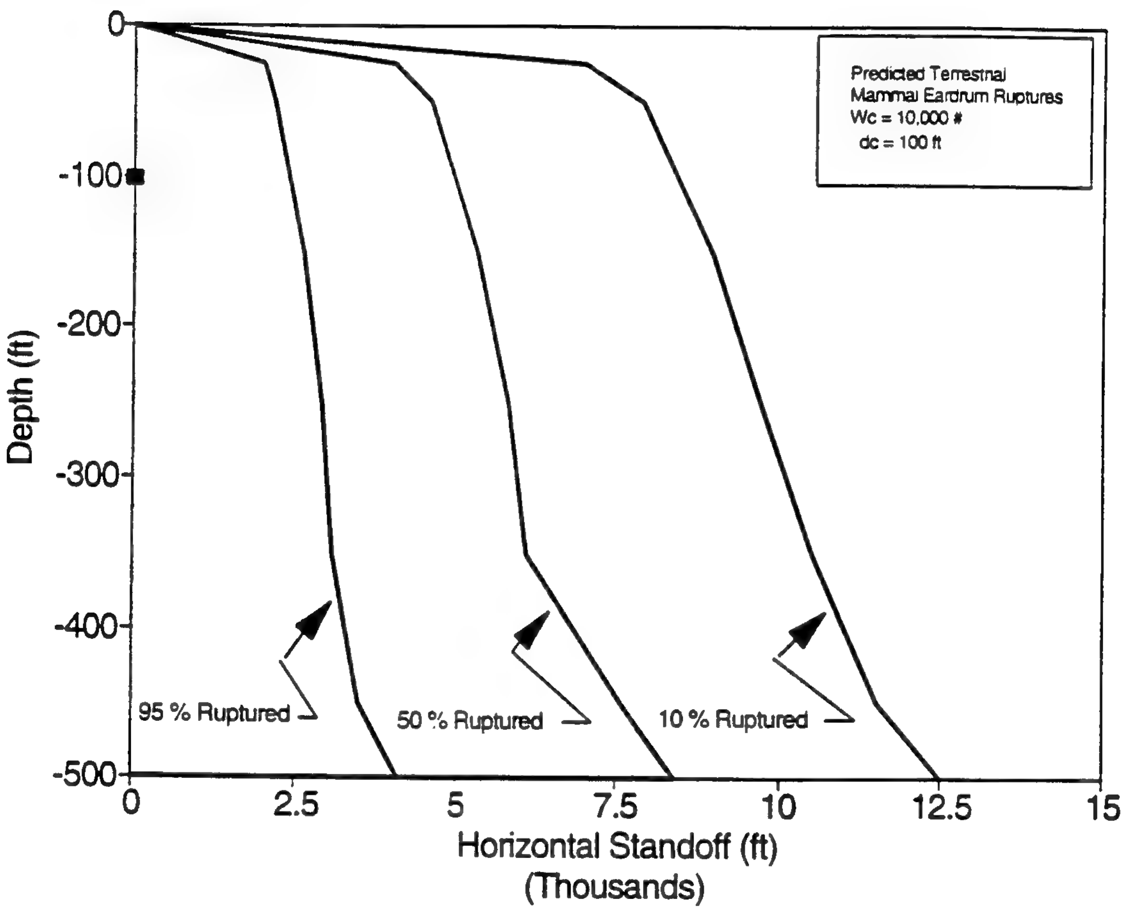
Table 8 provides the range of predicted standoffs for 95%, 50%, and 10% terrestrial mammal eardrum rupture for the 10,000-lb (4536-kg) charge using equation (2). Figure 11 shows the calculated 95/50/10 percent terrestrial mammal eardrum rupture contours.

Table 8. Predicted Ranges for Terrestrial Mammal Eardrum Rupture for a 10,000-lb (4536-kg) Charge[1].

MAMMAL DEPTH ft / (m)	95% RUPTURE RANGE ft / (m)[2]	50% RUPTURE RANGE ft / (m)[2]	10% RUPTURE RANGE ft / (m)[2]
50 / (15.2)	2150 / (655.3)	4000 / (1219.2)	7900 / (2407.9)
250 / (76.2)	2900 / (883.9)	5325 / (1623.1)	9750 / (2971.8)
500 / (152.4)	4070 / (1240.5)	8375 / (2552.7)	12,440 / (3791.7)

[1] 10,000-lb (4536-kg) at 100-ft (30-m) depth.
[2] Based on incremental shockwave energy (equation 2).

Source: CD-NSWC/UERD



Source: CD-NSWC/UERD

Figure 11. Eardrum Rupture Injury Contours for a 10,000-lb (4536-kg) Charge.

B.3.1. <u>Lethality as a Result of Auditory System Injury</u>

Todd, et al. (1993), reporting on the observed impacts of construction project blasting operations on seasonally resident humpback whales, noted that, "Humpback whales showed little behavioral reactions to the detonations, either in terms of decreased residency, resighting rates, or in terms of overall movements or general behavior. However, there seems little doubt that the increased entrapment rates were influenced by the long term effects of exposure to deleterious levels of sound.... Exposure to detonations can at least occasionally have harmful (lethal) effects." (Ketten, et al. [1993] provided a detailed pathological description of the eardrum injuries.)

The construction project differs significantly from the Navy project described in this document:

1. The whales were seasonal residents; marine mammals in the test area are expected to be transients and would probably not be exposed to high sound pressure levels from multiple detonations.

2. The construction project used a 1-nm (1.9 km) safety range for all charge weights -- from sub-1000 kg (2200 lb) to 5500 kg (12,125 lb). The Navy project described in this document will utilize a safety range which exceeds the 1 nm (1.9 km) used for all charge weights during the construction project.

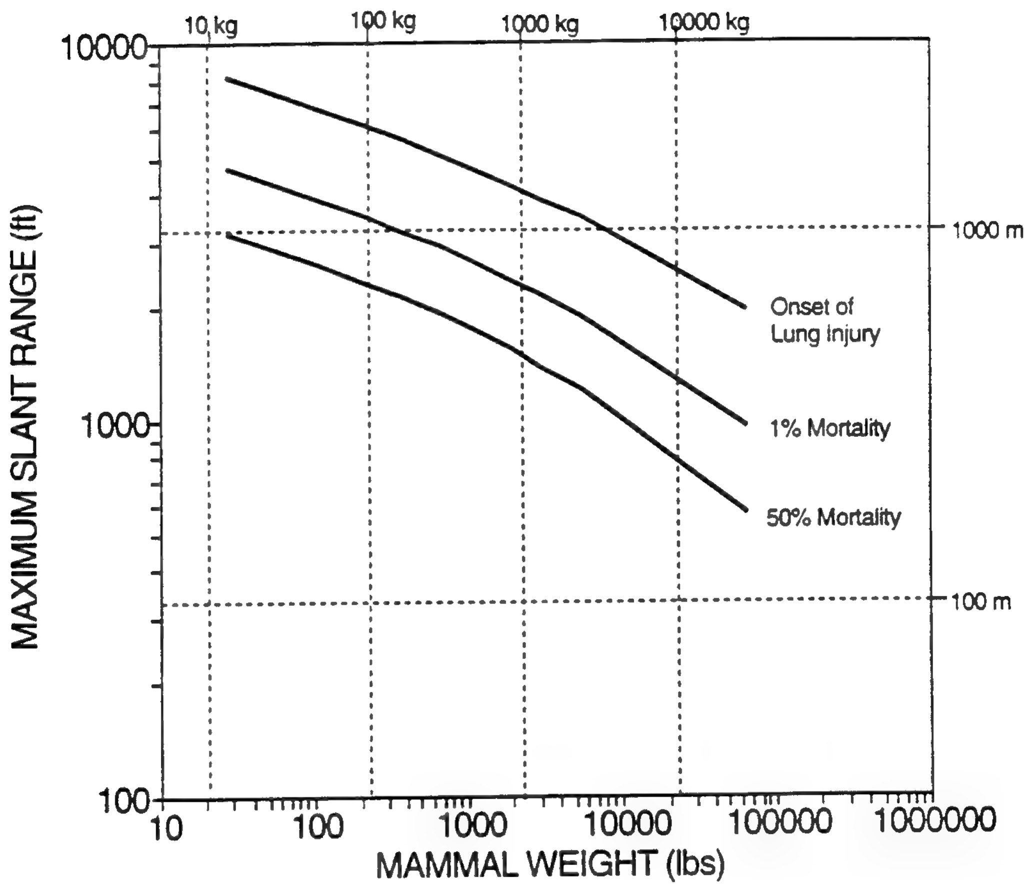
3. The blasting site was Bow Arm - a narrow, shallow fjord with rock sidewalls and a hard reflective bottom. The Navy test site is in ocean waters away from highly reflective side and bottom surfaces.

C. Calculated Injury Ranges for Marine Mammals

"An analysis of the information presented [in A and B] shows that marine mammals are probably less vulnerable to *gross* physical damage from underwater shock waves than are land mammals of comparable size. This is primarily because of adaptations to pressure changes which enable these animals to dive and, secondarily, because of the increased thickness of their body walls. In addition, when marine mammals are diving - particularly when they are deeper than about 150 m [495 ft] - they will probably be less vulnerable than when they are at or near the surface," (Hill, 1978).

Figure 12 combines the onset of lung injury, 1% mortality, and 50% mortality as a function of mammal weight curves from Figures 3, 5, and 7.

Figures 13 through 16 provide calculated range contours for 0% (onset of slight lung hemorrhage), 1% (onset of extensive lung hemorrhage), and 50% (extensive lung hemorrhage) mortalities, for the 10,000-lb (4536-kg) charge for representative cetaceans ranging from 3.3-ft-long/27-lb (1-m/12.2-kg) calf and 8-ft-long/384-lb (2.4-m/174-kg) adult dolphins to 20-ft-long/3110-lb (6.1-m/1410-kg) and 55-ft-long/64,800-lb (16.8-m/29,400-kg) whales. These cetacean sizes were previously used by Goertner (1982) and O'Keeffe and Young (1984) in previous assessments of the potential effects of underwater explosions on marine mammals.



Source: CD-NSWC/UERD, after Goertner (1982); Myrick, et al. (1990)

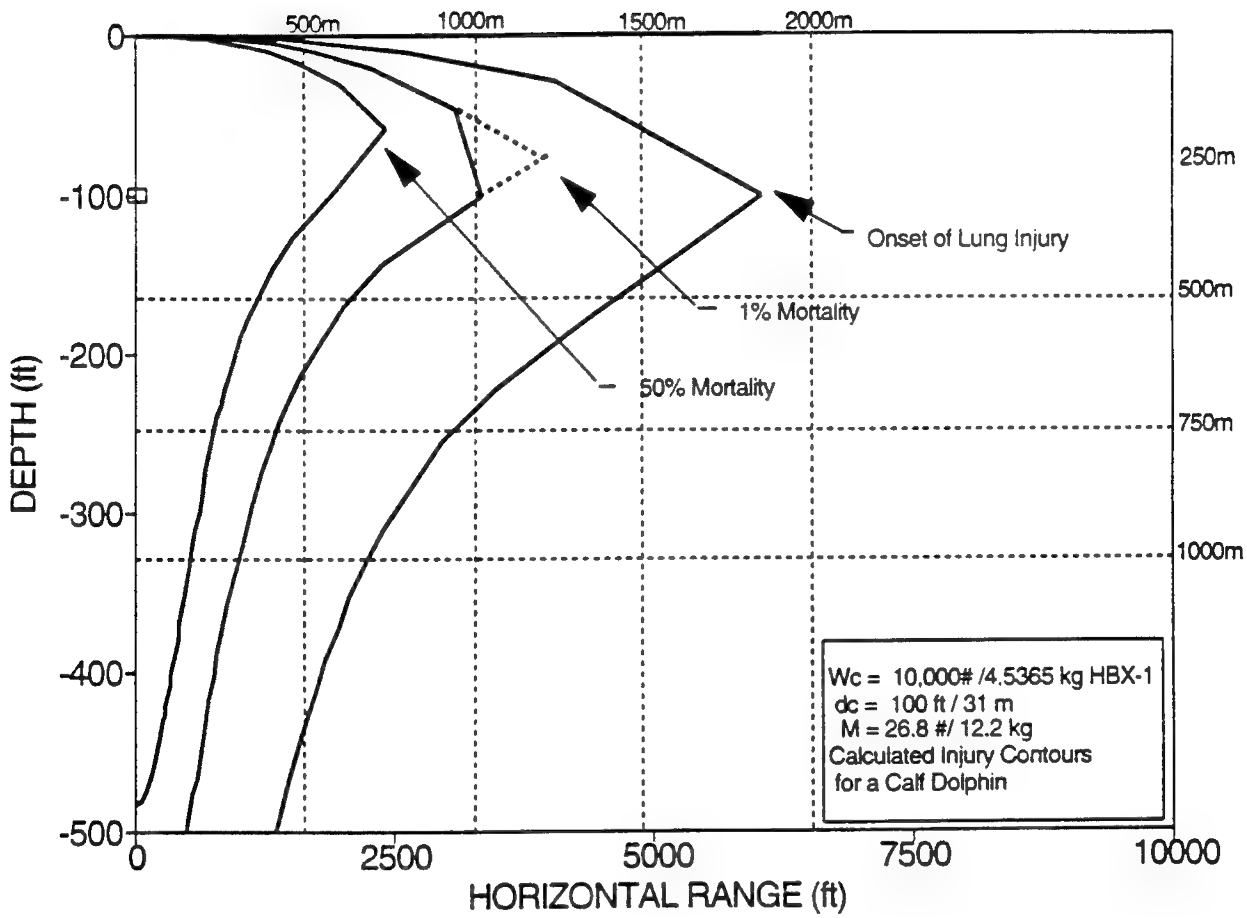
Figure 12. Calculated Injury Ranges as a Function of Mammal Weight for a 10,000-lb (4536-kg) Charge.

The internal organ injury ranges shown in Figures 12 through 16 are based on limited terrestrial animal test data and do not include any reduction for the inherent robustness of marine mammals which should significantly increase their resistance to these types of injuries. On the basis of the best available information, the ranges shown in these figures for internal organ and auditory system injuries are believed to be conservative. It should be noted that the mysticetes, because of their large body mass, should be significantly more resistant to internal organ injuries than to auditory system injury; i.e., baleen whales could be at a relatively high degree of risk for auditory system injury while at a very low degree of risk for injury to internal organs. The assumptions and calculations performed in this study would appear to be supportable by the data and observations of Todd, et al. (1993).

D. Potential Harassment from Underwater Explosions

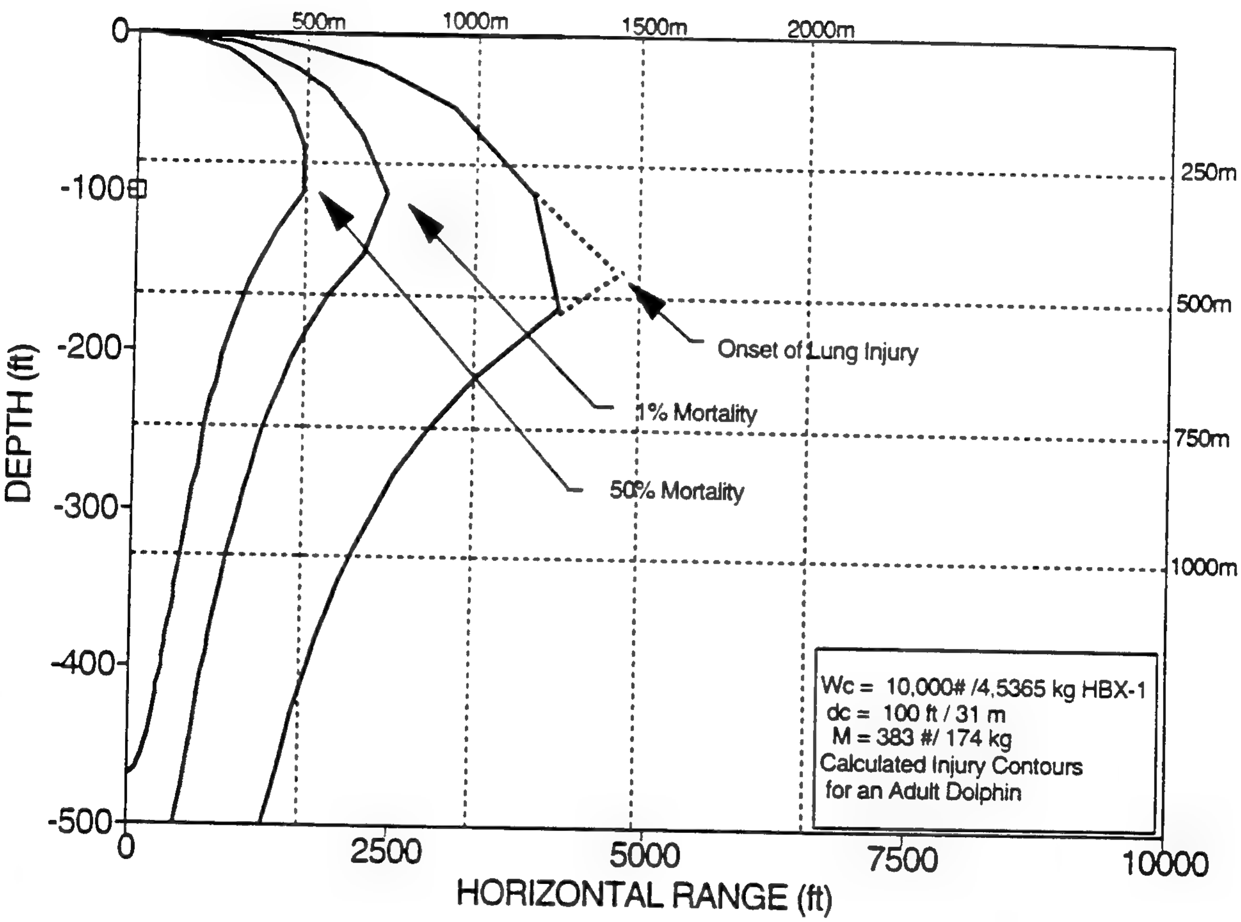
Harassment of marine mammals is defined in the Marine Mammal Protection Act (MMPA), 16 U.S.C. 1362 (as amended, Public Law 103-238, 108 Stat. 532, 557 [1994]), as "any act of pursuit, torment or annoyance which -

(i) has the potential to injure a marine mammal or marine mammal stock in the wild; or



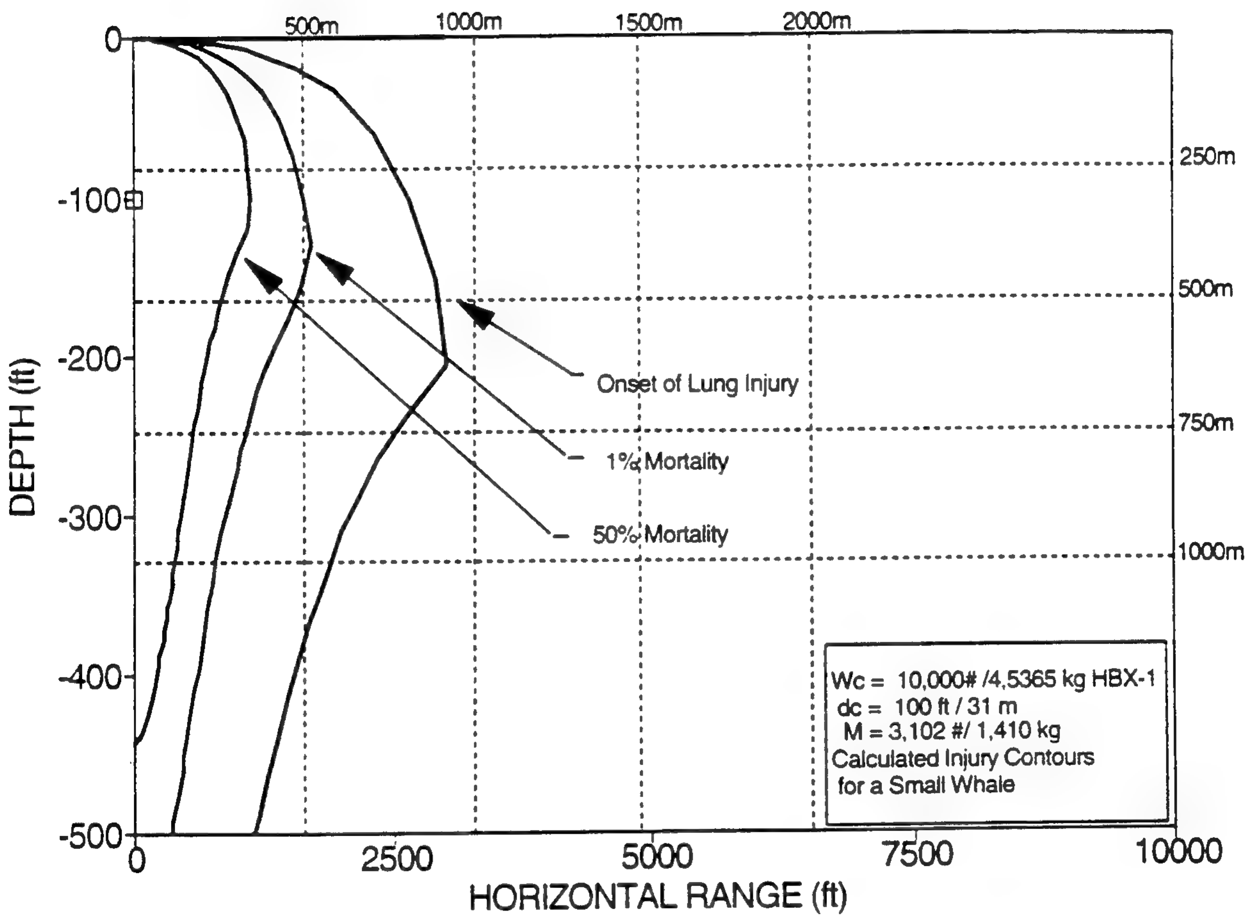
Source: CD-NSWC/UERD, after Goertner (1982), Richmond, et al. (1973), and Yelverton (1981)

Figure 13. Calculated Injury Contours for a Calf Dolphin from a 10,000-lb (4536-kg) Charge.



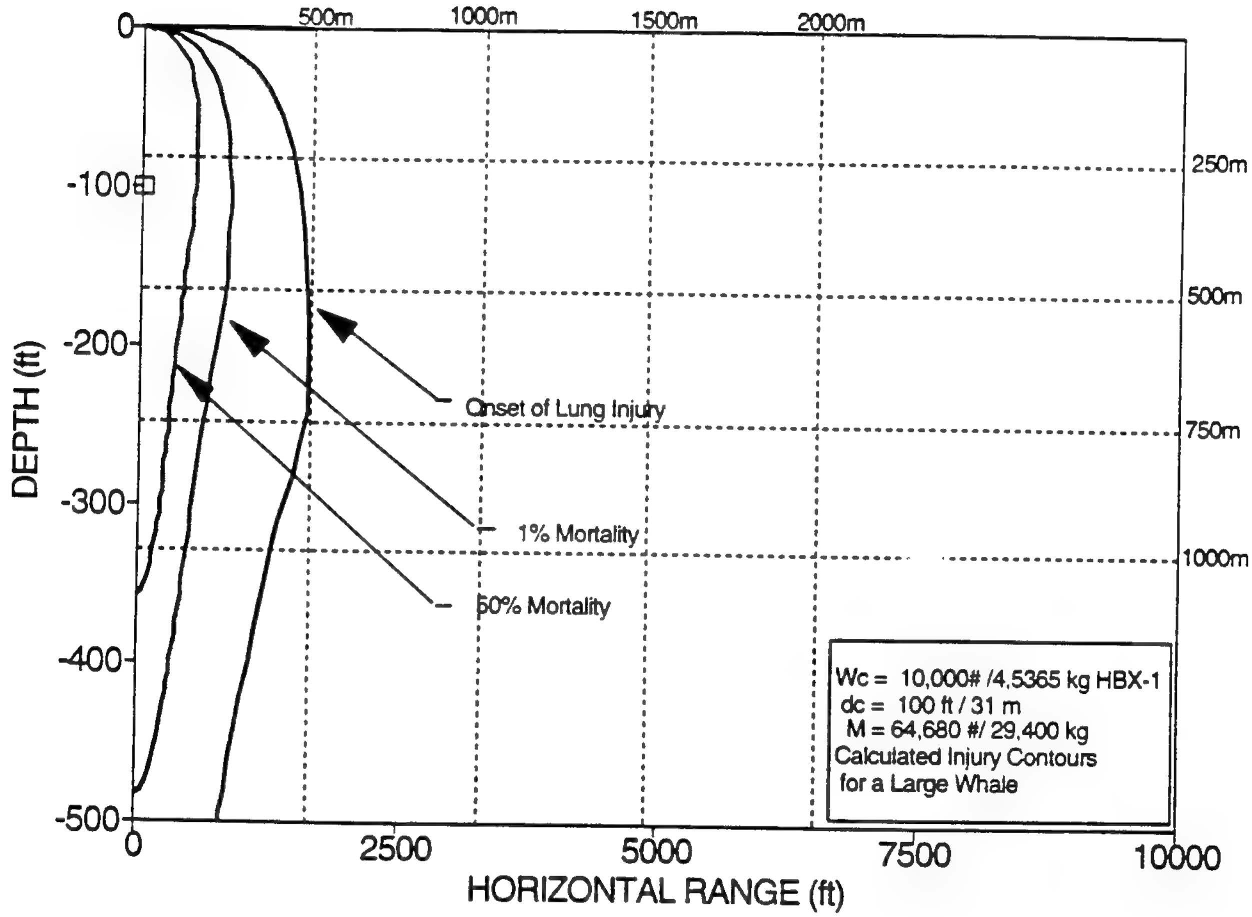
Source: CD-NSWC/UERD, after Goertner (1982), Richmond, et al. (1973), and Yelverton (1981)

Figure 14. Calculated Injury Contours for an Adult Dolphin from a 10,000-lb (4536-kg) Charge.



Source: CD-NSWC/UERD, after Goertner (1982), Richmond, et al. (1973), and Yelverton (1981)

Figure 15. Calculated Injury Contours for a Small Whale from a 10,000-lb (4536-kg) Charge.



Source: CD-NSWC/UERD, after Goertner (1982), Richmond, et al. (1973), and Yelverton (1981)

Figure 16. Calculated Injury Contours for a Large Whale from a 10,000-lb (4536-kg) Charge.

(ii) has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

"Level A harassment" means harassment described in paragraph (i) above and the term "Level B harassment" means harassment described in paragraph (ii) above.

Harassment of marine mammals is similarly defined in the Endangered Species Act (ESA), 16 U.S.C. 1531 to 1544 as "an intentional act or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding or sheltering."

D.1. Physical Discomfort/Tactile Perception

Occurrence of brief physical discomfort to cetaceans from the shockwave is inferred from data on voluntary human subjects exposed to the shockwave from a 1-lb (0.45-kg) pentolite charge and a 300-lb (136-kg) TNT charge (Christian and Gaspin, 1974). "This inference seems plausible given studies on dolphin skin sensitivity where the authors concluded that the most sensitive areas of the dolphin skin (mouth, eyes, snout, melon, and blowhole) are about as sensitive as the skin of the human lips and fingers (Ridgway and Carder, 1990 and 1993).

Overall skin sensitivity of dolphins equals that of humans (Ridgway and Carder, 1993). Skin sensitivity for... large whales has not been tested," (Moore, 1993).

Exposed to the shockwave from the 1-lb (0.45-kg) charge, human subjects reported feeling no stings or pressure at a 120-ft (36.6-m) range [3.0 psi-msec (20.4 Pa-sec) impulse and 96 psi (654 kPa) peak pressure]; feeling moderate stings at a 115-ft (35.1-m) range [3.3 psi-msec (22.5 Pa-sec) impulse and 98 psi (668 kPa) peak pressure]; and feeling strong stings at a 100-ft (30.5-m) range [4.2 psi-msec (28.6 Pa-sec) impulse and 115 psi (784 kPa) peak pressure]. Shockwave durations were 0.033, 0.035, and 0.040 msec; and calculated energy flux densities were 0.06, 0.06, and 0.08 in-lb/in^2 (1.1, 1.1, and 1.4 milli-Joules/cm^2), respectively. Exposed to the shockwave from the 300-lb (136-kg) charge at a 4050-ft (1235-m) range, human subjects heard "a muffled 'thud' or rumbling.... No sensation of pressure on the body was experienced by any of the four divers..." (Christian and Gaspin, 1974). Calculated shockwave parameters for the 300-lb (136-kg) test include an impulse of 1.9 psi-msec (12.9 Pa-sec), shockwave energy of 0.005 in-lb/in^2 (0.09 milli-Joules/cm^2) and a 17 psi (116 kPa) peak shockwave pressure. The shockwave duration was 0.12 msec.

Physical discomfort resulting from shockwaves from large charges do not readily fit the criteria from small charges. Consideration of partial impulse, energy flux density and peak shockwave pressure are used to assess the potential for

occurrence of physical discomfort. Brief physical discomfort is likely to occur at ranges such that a partial impulse of 3.3 psi-msec (22.5 Pa-sec) or greater is delivered within 0.035 msec. Tactile perception could occur in the volume of water where the total shockwave energy flux density exceeds 0.06 in-lb/in^2 (1.1 milli-Joules/cm^2) and the peak shockwave pressure exceeds 17 psi (116 kPa), but the partial impulse is less than 3.3 psi-msec (22.5 Pa-sec). Neither tactile perception nor brief physical discomfort is likely to occur at ranges where the total shockwave energy flux density is less than 0.06 in-lb/in^2 (1.1 milli-Joules/cm^2), or when the peak shockwave pressure is 17 psi (116 kPa) or less.

The occurrence of brief physical discomfort is considered to be independent of mammal type, size, or weight. The maximum horizontal ranges for brief physical discomfort and tactile perception as well as the shockwave peak pressures at these ranges for the 10,000-lb (4536-kg) charge are presented in Table 9. Brief physical discomfort would be very likely to occur at ranges less than the maximum values shown in column 2 of Table 9. Tactile perception would be extremely unlikely at ranges that exceed the maximum range values shown in column 4 of Table 9. Tactile perception is likely to occur at ranges intermediate to the two maximum range values shown in Table 9.

Figure 17 presents range contours for brief physical discomfort and tactile perception for the 10,000-lb (4536-kg) charge.

Table 9. Maximum Ranges for Brief Physical Discomfort from and Tactile Perception of Underwater Explosion Shockwaves from a 10,000-lb (4536-kg) Charge.

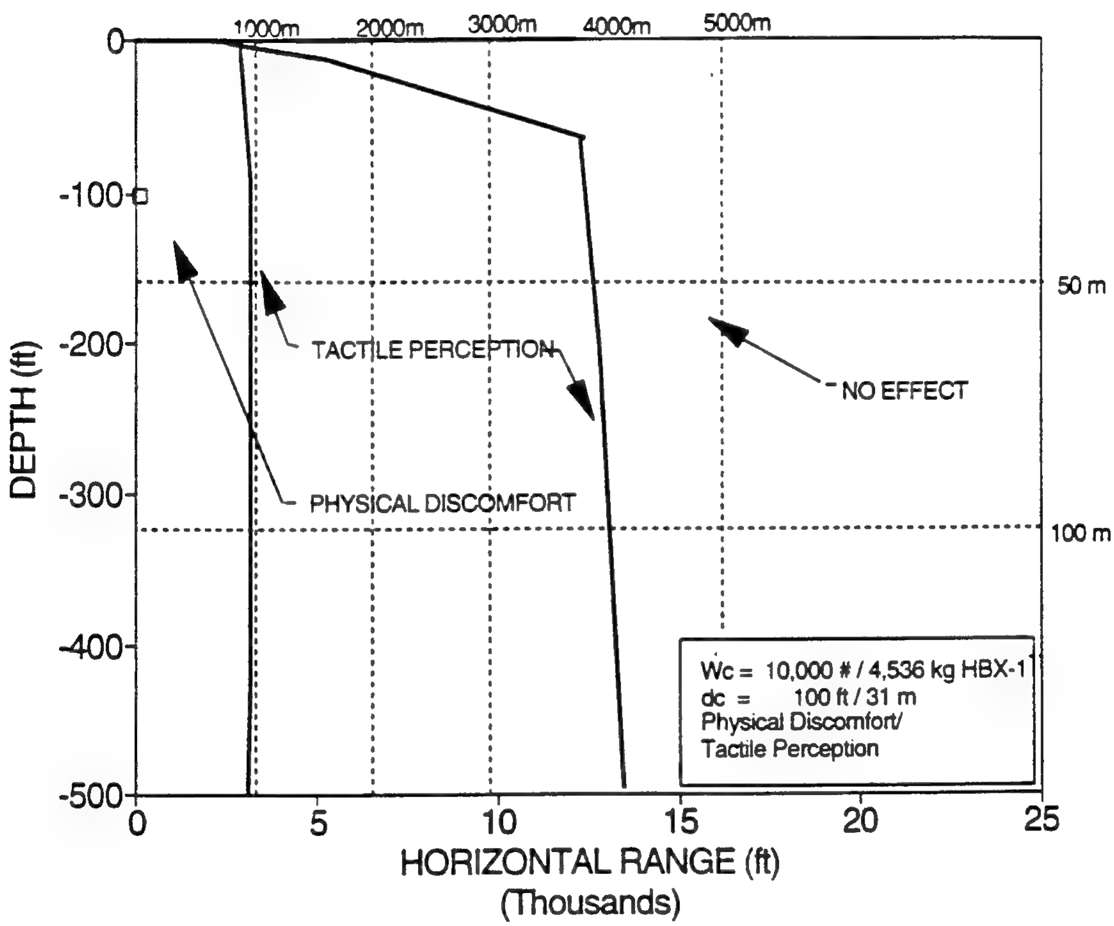
MAXIMUM RANGE FOR PROBABLE BRIEF PHYSICAL DISCOMFORT		MAXIMUM RANGE FOR PROBABLE TACTILE PERCEPTION	
Range ft/(m)	P_{max} psi/(kPa)	Range ft/(m)	P_{max} psi/(kPa)
3100 / (945)	83 / (566)	13,830 / (4215)	17 / (116)

Source: CD-NSWC/UERD, after Christian and Gaspin (1974)

The non-injurious physical discomfort which would only occur to animals which were undetected by active mitigation measures is of such brevity that any disruption of behavioral patterns would be expected to be temporary and not harmful to the animals.

E. Effects of Bulk Cavitation

"Cavitation occurs when compression waves, which are generated by the underwater detonation of an explosive charge, propagate to the surface and are reflected back into the water as rarefaction waves. These rarefaction waves cause a state of tension to occur within a large region of water. Since water cannot ordinarily sustain a significant amount of tension, it cavitates and the surrounding



Source: CD-NSWC/UERD

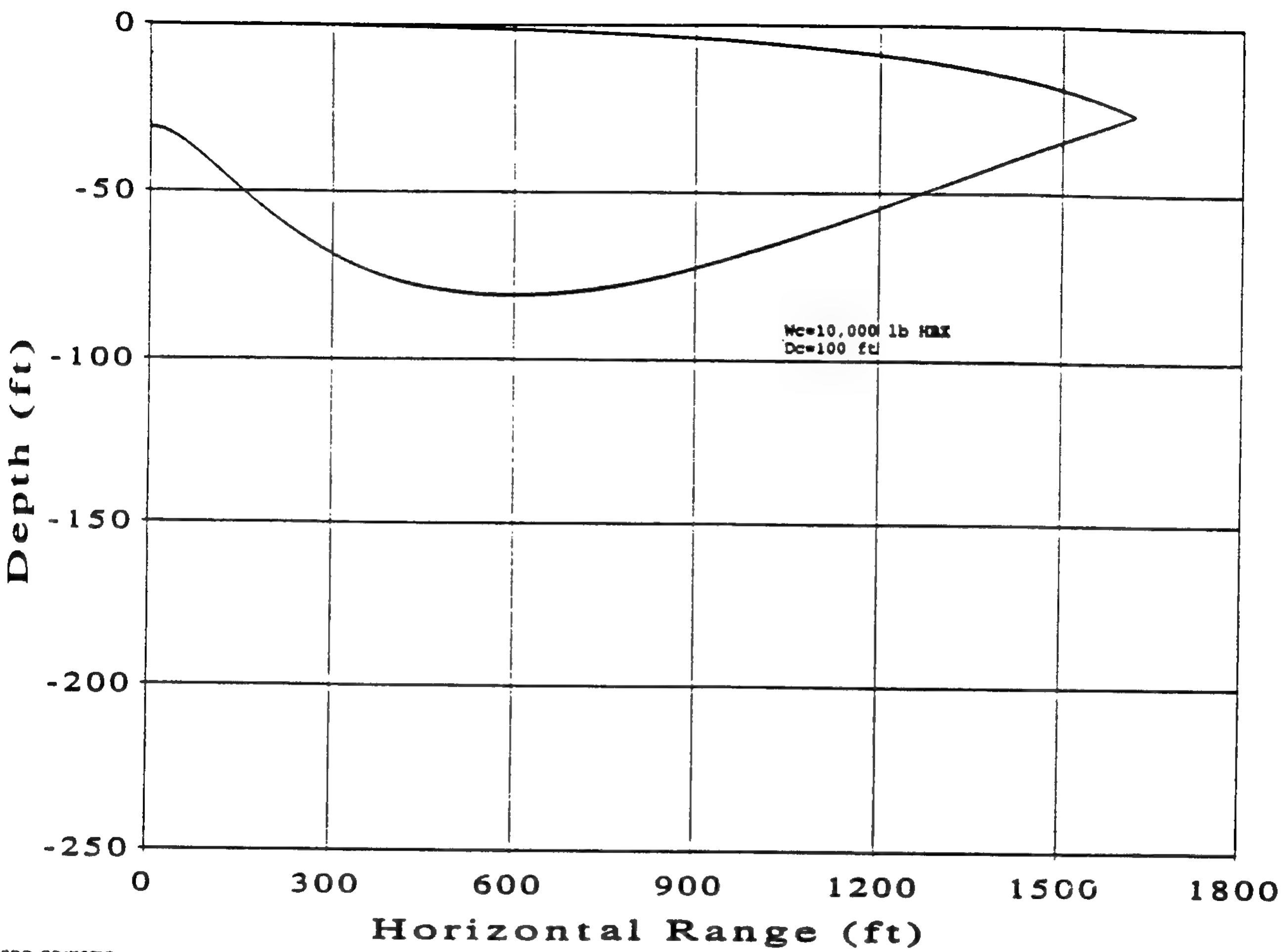
Figure 17. Contours for Brief Physical Discomfort and Tactile Perception from a 10,000-lb (4536-kg) Charge.

pressure rises to the vapor pressure of water. The region in which this occurs is known as the bulk cavitation region, and it includes all water which cavitates at any time after the detonation of the explosive charge. The upper and lower boundaries, which show the maximum extent of the cavitated region, form what is referred to as the bulk cavitation envelope. ...The time of bulk cavitation closure is defined as the time at which the lower boundary displacement equals the surface layer displacement. It is at this time that the accreting surface layer and the accreting lower boundary collide and generate the water hammer pressure pulse," (Costanzo and Gordon, 1989).

The direct effects of cavitation on marine mammals are unknown. Presence within the negative pressure cavitation zone could injure the auditory system or lungs. A mammal located at (or in the immediate vicinity of) the cavitation closure depth would be subjected to the water hammer pressure pulse. The magnitude of the closure impulse can range from insignificant (smaller charges) to substantial (larger charges); however, at the calculated ranges for onset of lung hemorrhage as well as both 1% and 50% mortalities, the closure impulse is less than the required shockwave impulse required to cause the stated degree of injury.

The presence of a marine mammal within the cavitation region created by the detonation of small charges could annoy, injure, or even increase the severity of the injuries caused by the shockwave. The area of cavitation from a 10,000-lb

(4536-kg) charge would be expected to be an area of near total physical trauma. It is not expected that any fish or smaller animals would survive the combined effects of the relatively high shockwave impulses and the violent cavitation. The maximum lateral extent of this cavitation area is 1620 ft (494 m) for the 10,000-lb (4536-kg) charge, utilizing the methods of Costanzo and Gordon (1989). (Refer to Figure 18 for delineation of the cavitation region.) Peak shockwave pressure at the above horizontal distance from the charge is 159 psi (1084 kPa).



Source: Costanzo and Gordon (1989)

Figure 18. Bulk Cavitation Region - 10,000-lb (4536-kg) Charge.

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Ridgway, S. H., and D. A. Carder; 1990. Tactile sensitivity, somatosensory responses, skin vibrations, and the skin surface ridges of the bottlenose dolphin, *Tursiops truncatus*. pp. 163-179 in: Sensory Abilities of Cetaceans, J. Thomas and R. Kastelein (eds. Plenum Press, New York, 710 pp.)

Ridgway, S. H., and D. A. Carder; 1993. Features of dolphin skin with potential hydrodynamic importance. IEEE Engineering in Medicine and Biology: 83-88.

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APPENDIX D

CRITERION FOR MARINE MAMMAL ACOUSTIC DISCOMFORT

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APPENDIX D

This appendix describes a criterion for acoustic discomfort in marine mammals. The criterion is used to define an acoustic discomfort range for marine mammals which may occur near underwater detonations. This information is used in the Environmental Consequences section of the DEIS.

TABLE OF CONTENTS

INTRODUCTION

An underwater explosion produces pressure pulses that have the potential for damaging the hearing of sea mammals that are too close to the explosion. Criteria for use in determining hearing-safe ranges have been developed for sea mammals exposed to underwater detonation of 10,000-lb charges.

Investigators with expertise in underwater-explosion acoustics and experts in marine-mammal hearing have agreed that acoustic-safety criteria for mammals exposed to underwater noise should be based on the amount of acoustic energy that impinges on the mammal ear.

Hearing threshold, which varies with frequency, is the quietest sound that can be heard. Hearing safety limits lie considerably above the hearing threshold. The most conservative safety limit is the highest sound level that causes no temporary threshold shift (TTS). A danger limit is the lowest sound level that causes permanent threshold shift (PTS), which is hearing loss.

The most meaningful criterion for determining acoustic safe ranges for sea mammals would be one that is based on measurements of TTS resulting from exposure to underwater noise. For underwater detonations such criteria should be species-specific and based on TTS measured for mammals exposed to underwater explosions.

The following summarizes the rationale and assumptions on which the predictions for SEAWOLF are based.

METHODOLOGY

Hearing thresholds for odontocetes and pinnipeds exposed to pure tones (*i.e.*, sine waves) of at least one-second duration have been measured. An exhaustive search by Richardson *et al* has revealed no available hearing-safety data (TTS or PTS) for any sea mammals.[1] Therefore, other methods must be used to estimate the potential for acoustic damage.

There are data for human underwater tolerance limits (levels that are uncomfortable but cause no TTS). Some measurements were made on hooded divers exposed to underwater explosions.[2] Unfortunately, these data could not be used because we have no information on the amount of attenuation provided by the hoods.

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[1] Richardson, W. J, Greene, C. R., Malme, C. I. and Thomson, D. H., *Marine Mammals and Noise*, Academic Press, Inc., San Diego, CA, 1995.

[2] Wright, H. C., Davidson, W. M. and Silvester, H. G., *The Effects of Underwater Explosions on Shallow Water Divers Submerged in 100 Feet of Water*, Medical Research Council, Royal Naval Personnel Research Committee, RNP 50/639, UWB 21, RNPL 4/50, October 1950.

Data obtained from unhooded humans immersed in water and exposed to brief pure tones, were used, assisted by human in-air data, to construct an underwater hearing-safety limit for marine mammals. This limit was then applied to define a very conservative safe range for exposure to an underwater detonation of a 10,000-lb explosive charge.

HUMAN HEARING UNDER WATER

One study on humans measured threshold shift after 15 minutes' exposure, both in air and underwater, to a 3500 Hz pure tone.[3] Because these data are for long exposure to pure tones, they are not applicable to our problem.

Figure 1 shows underwater hearing thresholds for odontocetes and humans.[4,5] The solid human-data curve does not have the same slope as the odontocete data, but it lies very close at 1500 Hz, the frequency at which human tolerance level was also measured.

The plotted square is a hearing-tolerance level, found by exposing hoodless divers to one-second-duration 1500-Hz tones from a source directly in front of them.[5] The tones were gradually increased in level by 1 dB until the divers wanted to go no further. An in-air hearing test conducted within 5 minutes of the underwater test showed no hearing damage and no TTS. The plotted square is useful as a conservative (no TTS) limit for sea mammals, but a limit is needed at more than one frequency. To obtain this limit, data on human hearing in air were used.

[3] Smith, P. F., Howard, R., Harris, M. and Waterman, D., *Underwater Hearing in Man: II. A Comparison of Temporary Threshold Shifts Induced by 3500 Hz Tones in Air and Underwater*, Report Number 608, U.S. Naval Submarine Medical Center, Groton, CT, 1970

[4] Richardson, W. J. *et al*, *Effects of Noise on Marine Mammals*, LGL Ecological Research Associates, Inc., Bryan, TX, done for Mineral Management Service, Herndon, VA, PB91-168914, Feb 91 [p. 180]

[5] Montague, W. E., and Strickland, J. F., *Sensitivity of the Water-Immersed Ear to High- and Low-Level Tones*, J. Acoust. Soc. Am. 33(10):1376-1381 (1961)

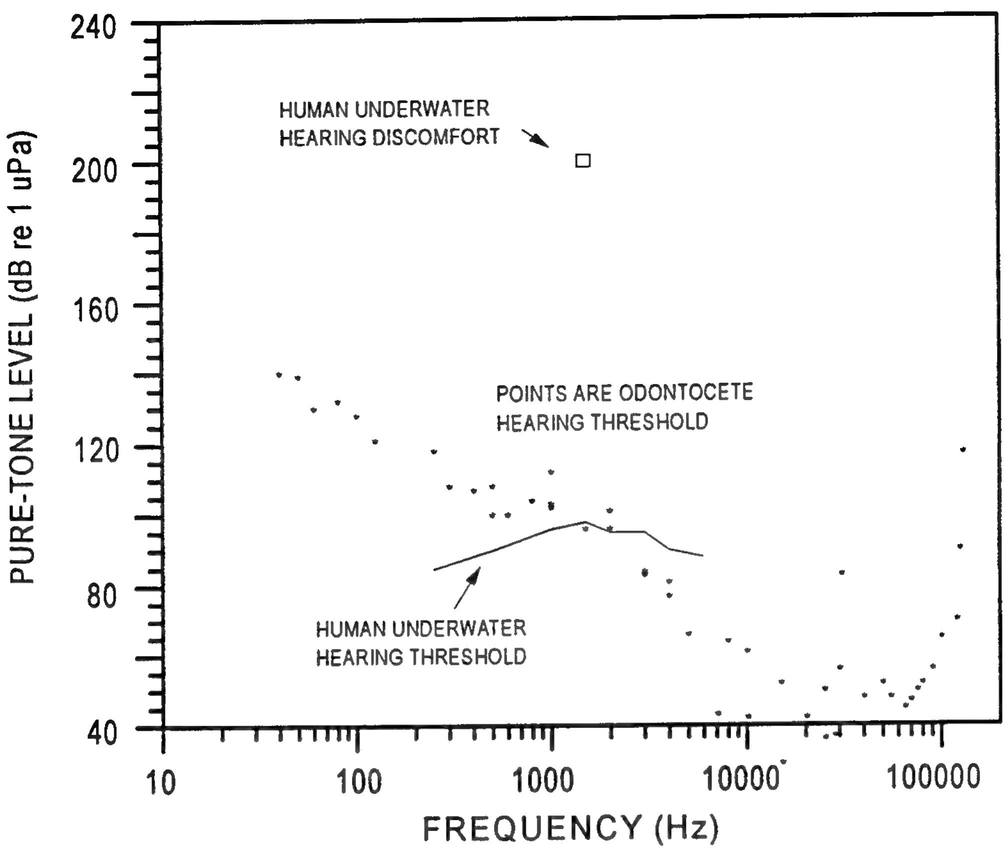

FIGURE 1. Odontocete and Human Underwater Hearing Thresholds

There are human data in air for threshold, discomfort and pain.[6,7] Figure 2 shows these levels. In Figure 3 the in-air data have been shifted by 100 dB, so that the human threshold matches the odontocete threshold in the 100 to 1000 Hz range. The discomfort and pain curves have been shifted by the same amount. The shifted "human pain" and "human discomfort" curves lie just above the measured-in-water human-tolerance data point (the square); this gave us confidence that use of the in-air data was not completely unreasonable. The dotted line was then drawn through the square and parallel to the upper in-air curves. This line can then be used as a safety limit for continuous tones.

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[6] Everest, F. A., *The Master Handbook of Acoustics*, 3rd ed. (Tab Books, McGraw-Hill, N. Y., 1994) [p. 43]

[7] Edge, P. M., Jr., and Mayes, W. H., *Description of Langley Low-Frequency Noise Facility and Study of Human Response to Noise Frequencies Below 50 cps*, NASA TN D-3204, 1966.

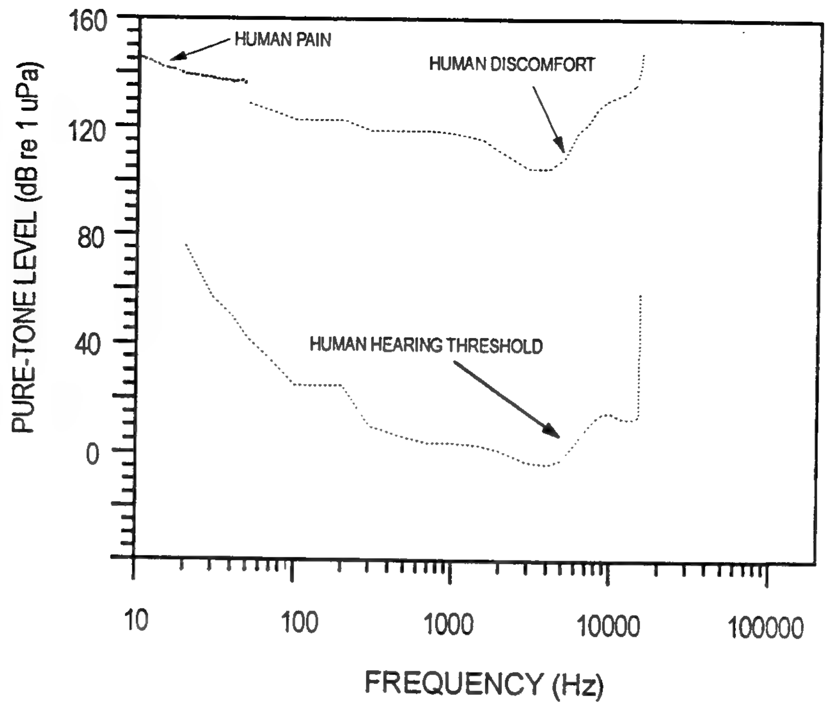

Figure 2. Human In-Air Hearing Threshold, Discomfort and Pain Levels

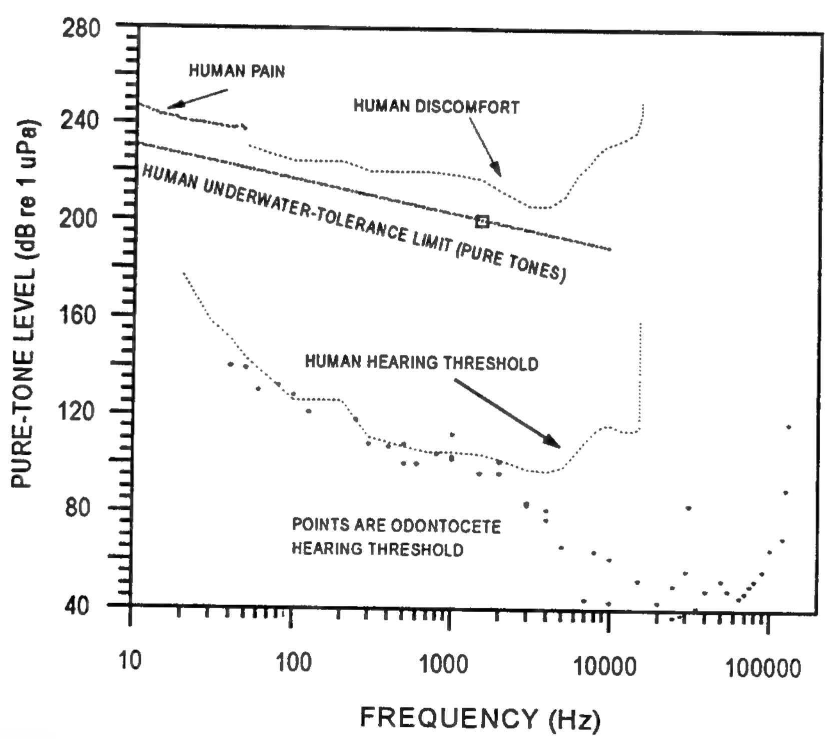

Figure 3. Human In-Air Limits Shifted to Match Odontocete Data: Setting Slope of Human Underwater Limit

Because human and dolphin hearing are comparable at their respective frequencies of best hearing, it was suggested that the method of shifting the human in-air data be modified. The dolphin frequency range reflects their specialized use of high-frequency sound. Therefore, to extrapolate from human to dolphin hearing mechanics, we have shifted the human auditory curve up in frequency by a factor of ten to match the range of the dolphin hearing curve. The level of the human curve (see Figure 2) has also been shifted up by 45 dB to match the odontocete threshold level. The discomfort and pain curves have been shifted by like amounts. Since we now can no longer make use of the single human underwater-tolerance data point (the square in Figure 3), we proposed the straight line that skims the bottom of the human-discomfort curve in Figure 4 as the revised safety limit for sea-mammal hearing.

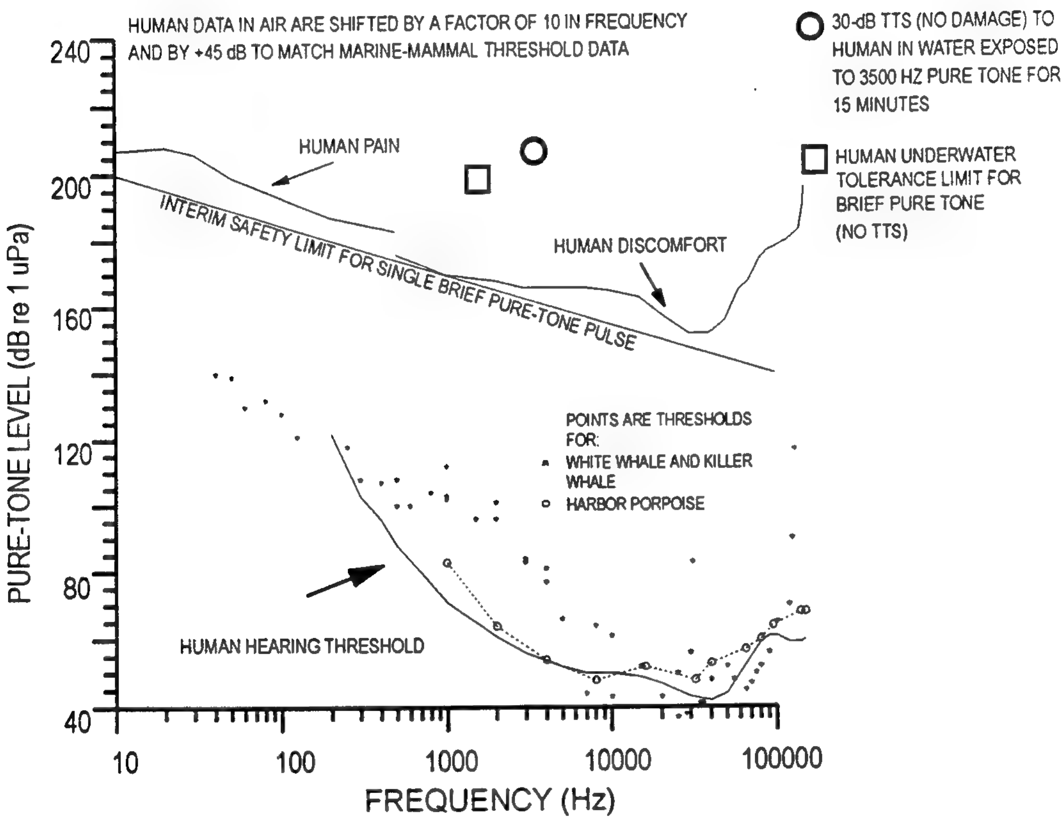

Figure 4. Interim Marine-Mammal Safety Limit for Pure Brief Tones: Based on Shifted, Human In-Air Data

The line in Figure 4 is 30 dB lower than the very conservative human underwater-tolerance limit presented in Figure 3. An additional indication of how conservative this line is for humans is the circle plotted in Figure 4. Humans were exposed to a 3500-Hz pure tone for 15 minutes. Two minutes after exposure, a TTS of 30 dB (no damage) was measured.[8]

[8] Smith, P.F., Howard, R., Harris, M. and Waterman, D., Underwater Hearing in Man: II. A Comparison of Temporary Threshold Shifts Induced by 3500 Hertz Tones in Air and Underwater, Submarine Medical Research Laboratory, U.S. Naval Base, Groton, Conn., 15 Jan 1970

In order to convert the above limit to energy, so that it can be compared with explosion output, we made use of the integration time of the ear. For humans, the integration time is about 0.1 to 0.2 seconds. Because we could find no clear value for the integration time of marine mammals, we have used 0.1 seconds, which appears conservative for porpoises [9], to define an underwater hearing-safety limit for humans, which was originally proposed as a "sea-mammal hearing-safety limit".

Figure 5 shows how the criterion can be applied to the calculated energy field. The new "interim safety limit" (Figure 4), has been converted to energy and is plotted as a dotted line. Considering the basis for its derivation, we believe this should be viewed as a criterion for acoustic discomfort or annoyance.

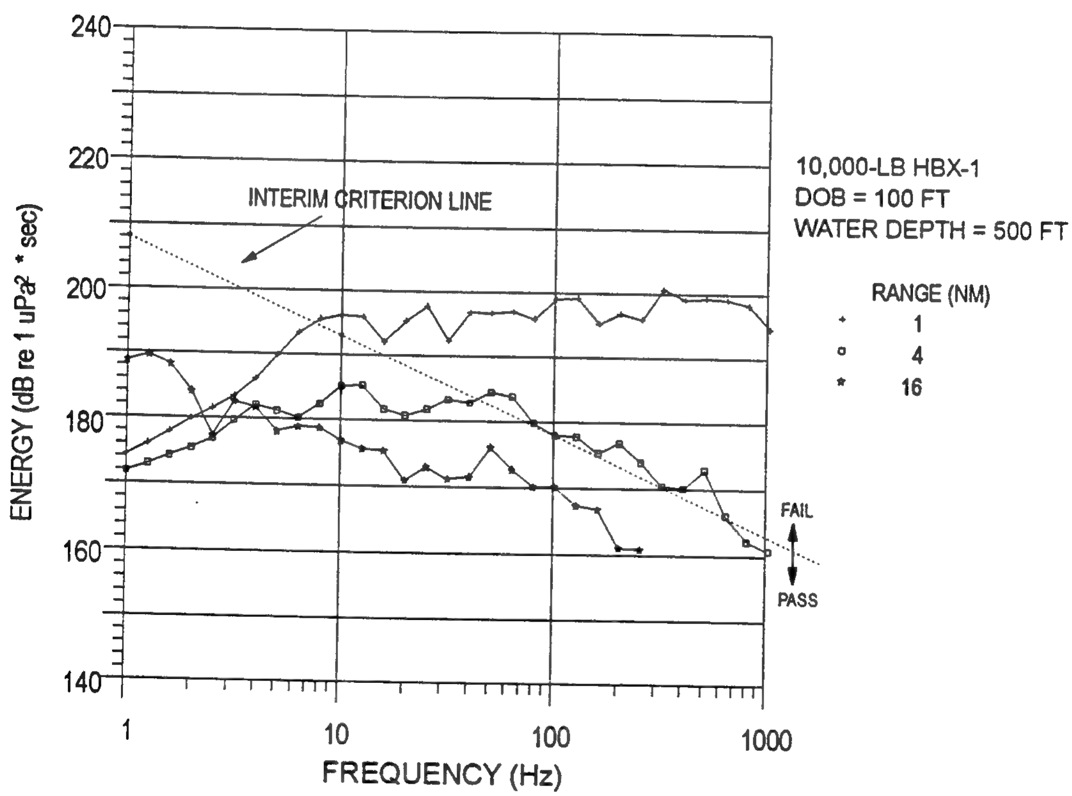

Figure 5. Example of Application of Interim Hearing-Safety Limit

[9] Johnson, C. S., *Relation between Absolute Threshold and Duration-of-tone Pulses in the Bottlenosed Porpoise*, J. Acoust. Soc. Am. 43 (4) 757-763, 1968.

Although audiograms have been measured for some odontocetes, the only information available for baleen whales is based on observation and anecdotal information.[10,11] Figure 6 shows representative hearing ranges for ondontocetes and baleen whales.[12] Since these whales regularly and repeatedly produce source levels of 180 to 185 dB in the lower frequencies of this range without deafening themselves, the criterion we have employed should be conservative for them also.

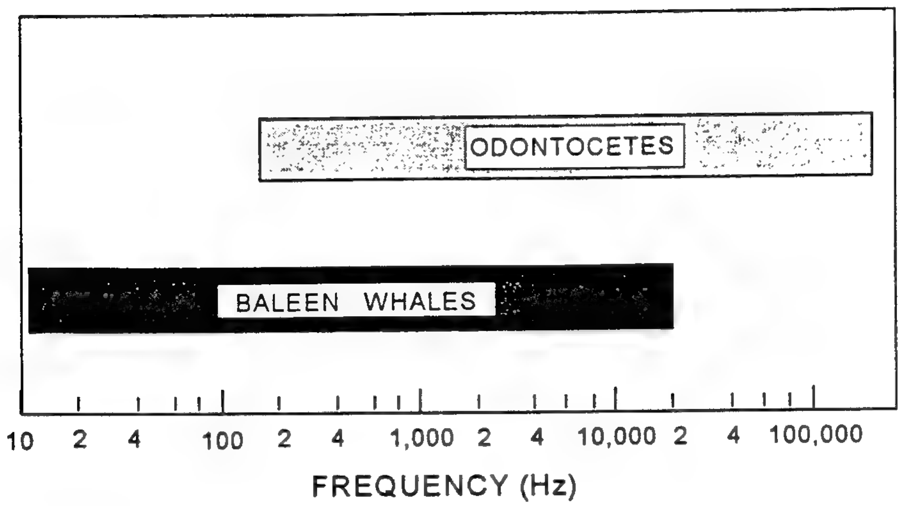

Figure 6. Representative Hearing Ranges for Large Whales and Dolphins

METHOD OF CALCULATION

The pulse train from a relatively shallow underwater explosion consists of a direct shock wave closely followed by companion surface-reflected and bottom-reflected pulses of opposite sign. For a 10,000 lb charge, a 100- or 200-ft charge depth is "relatively shallow".

The procedure for dealing with explosion pulses is to:

1) calculate the pressure-vs-time (p-t) waveform;
2) obtain the spectrum as energy/Hz;
3) integrate the spectrum to get energy/(1/3-octave band);
4) compare this energy directly with the safety limit.

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[10] Ketten, D. R., *The Marine Mammal Ear: Specializations for Aquatic Audition and Echolocation*. p 717-750 in The Biology of Hearing, Springer-Verlag, Berlin, 1991.

[11] Ketten, D., *The Cetacean Ear: Form, Frequency, and Evolution*. p 53-75 in Marine Mammal Sensory Systems, Plenum, New York, 1992.

[12] Ketten, D. *et al*, Marine Mammal Bio-Acoustics Short Course, Orlando, FL, 1995.

T p-t waveform is calculated with the REFMS computer code[13], Version 5.0. A water s d-speed profile and a bottom profile are required. A charge size and depth are chosen. Then, for a given range, waveforms are calculated at the desired depths (in this case, selected mammal locations). Energy spectra are obtained from the p-t waveforms by standard methods.

For the SEAWOLF calculations, we employed sound-speed profiles measured in the two proposed test areas. To be conservative, we have used the complete calculated pulse train even if it contains pulses separated by more than 0.1 seconds. (It could be argued that pulses separated by more than 0.1 seconds allow the ear to recover, and so the pulses should be considered individually.)

DISCUSSION OF RESULTS

Using the limited number of archival sound-speed profiles available for the two proposed test sites, calculations were made of the acoustic environment to which sea mammals might be exposed as a result of detonating 10,000-lb charges for the SEAWOLF shock test. The mammal depth was varied from 50 feet to 400 feet (in 500 feet of water). Plots of energy (in 1/3-octave bands) were made for ranges from one nautical mile (nm) to as much as 6 or 8 nm. The interim criterion line has been plotted along with the energy level as a function of mammal depth at the indicated range.

Figures D-1 through D-6 show selected plots for the Norfolk test area; Figures D-7 to D-11 are results for the Mayport area. Although the water column in the Mayport area seems to have a rather stable velocity structure, there are very few archival profiles available. Profiles in the Norfolk area are quite variable. In the latter region, vortices from the Gulf Stream can cause wild swings in both sound-speed and current profiles in as little as 24 hours. Since the Mayport test area is also adjacent to the Gulf Stream, one might expect variability similar to that observed near Norfolk.

Although we do not have energy plots at 6 and 8 nm for all the cases shown in Appendix D, we can generalize to some extent about the calculations made using the archival profiles from these two areas. For the same profile, the 1/3-octave-band energy levels tend to drop by 5 to 10 dB going from 1 to 2 nm, another 5-10 dB going from 2-4 nm, another 5 dB from 4-6 nm, and probably another 5 dB going from 6-8 nm. In addition, the drop-off with range becomes faster as the frequency increases.

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[13] Britt, J. R., Eubanks, R. J., and Lumsden, M. G., *Underwater Shock Wave Reflection and Refraction in Deep and Shallow Water: Volume I - A User's Manual for the REFMS Code (Version 4.0)*; Science Applications International Corporation, P.O. Box 469, St. Joseph, LA 71366-0469, DNA-TR-91-15-V1, June 1991.

For both areas, archival profiles can give us only an indication of the variability one might expect during a given time period. The cases shown are for profiles most representative of the variability to be expected from April to July in the two areas

Generally, the interim safety limit, which we consider to be extremely conservative insofar as acoustic damage to the mammal ear, indicates a probable range for discomfort or annoyance from 4 to 6 nm. The trend is for the "safe" range to become shorter later in the summer and into early fall. This is a function of the increasing temperature of the water.

There is a variation with mammal depth, however. In general, the deeper the mammal, the lower the explosion-noise level at range. In some cases, the calculated "safe" range for a mammal at 100 feet is greater than 6 nm, even though all other depths indicate a range within 4 to 6 miles. When we make calculations for a depth of 50 feet, however, the curve tends to drop below the 100-foot curve. (See Figures D-6 and D-11.)

While most of the calculations were performed for frequencies up to 1 kHz, a few have been extended to 10 kHz and beyond. (See Figures D-4 to D-6 and Figures D-9 to D-11.) Because acoustic attenuation at 10 kHz is extremely high and increasing rapidly, the explosion energy falls off much more rapidly above this frequency. This is of most interest for the odontocetes at ranges of 6 nm and beyond, because their frequencies of best hearing tend to be in the 30 to 40 kHz region.

Although the April profiles show portions of some of the curves above the criterion at 6 nm, these tend to be in the frequency range below 100 Hz, which is probably below the frequency of best hearing for the baleen whales. The parts of these curves that lie above the criterion between 100 and 1000 Hz (probably the range of best hearing for the baleen whales) are at or below the levels at which these animals regularly and repeatedly produce vocalizations that do not deafen them.

CONCLUSIONS

There are no existing data applicable to the definition of a meaningful criterion for potential auditory injury to marine mammals exposed to underwater explosions. The interim acoustic-energy limit developed for use in predicting the acoustic impact of the SEAWOLF detonations is based on human in-air data. Evidence that indicates how conservative this limit is for people has been provided by studies made with humans exposed to brief pure tones underwater (no TTS) and humans exposed to pure tones for 15 minutes underwater (30 dB TTS: no damage).

RECOMMENDATIONS

Until reliable measurements have been made of temporary threshold shift, TTS, that is directly attributable to exposure of marine mammals to underwater explosions, this interim criterion should be used only for defining ranges for "acoustic discomfort" or annoyance.

One must keep in mind that the actual acoustic field on any given day will depend on the sound-velocity structure at that time and on the actual bottom sediment and structure in the area. Calculations made using archival information provide only an estimate of what one should expect. Actual *in situ* profile measurements and calculations made on site during the test series must be used to guide those who will be responsible for monitoring and mitigation.

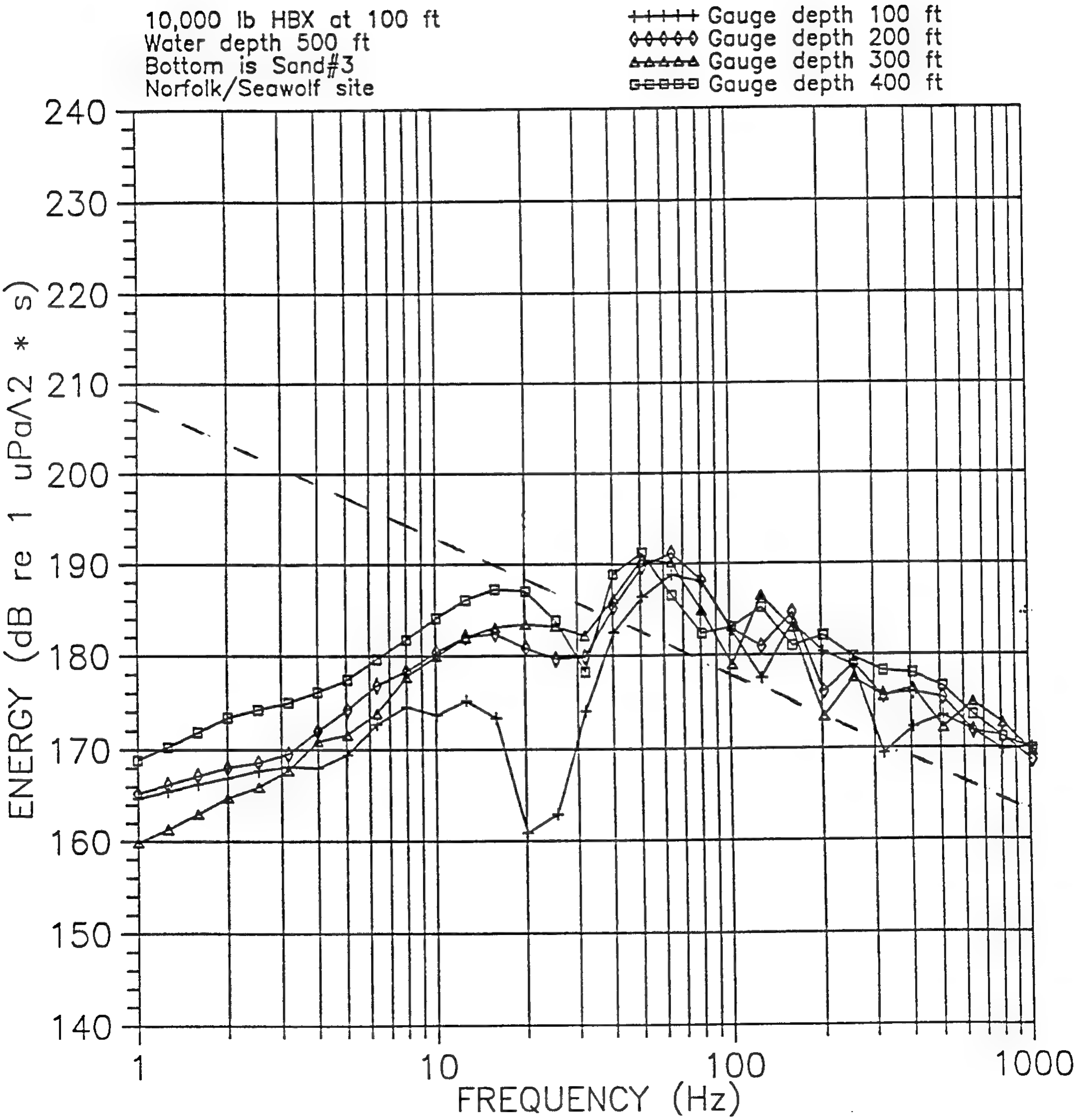

FIGURE D-1. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA: APRIL; RANGE = 4 NM; MAMMAL DEPTH = 100 TO 400 FT

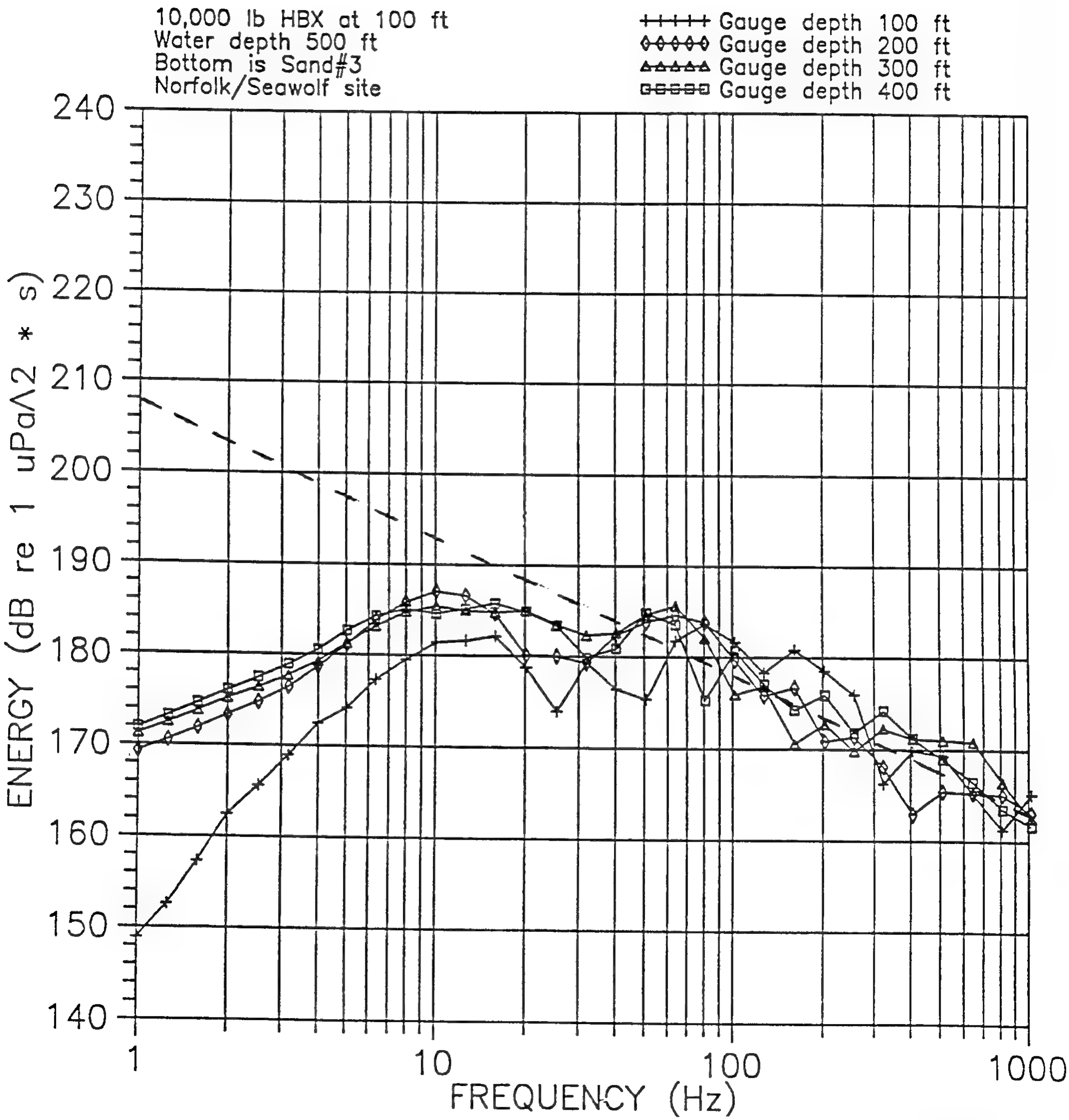

FIGURE D-2. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA
APRIL; RANGE = 6 NM; MAMMAL DEPTH = 100 TO 400 FT

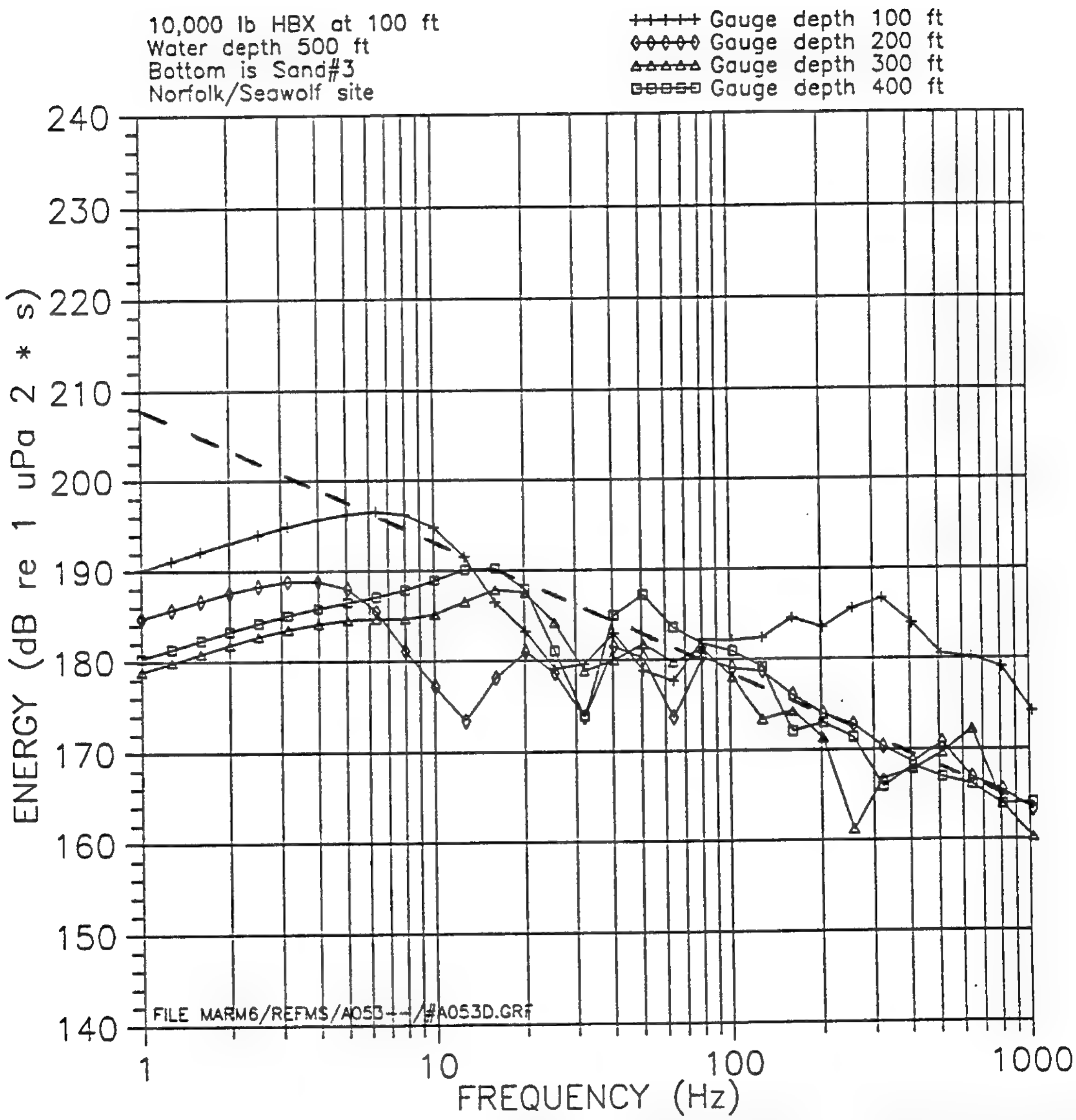

FIGURE D-3. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA
MAY-EARLY JUNE; RANGE = 4 NM; MAMMAL DEPTH = 100 TO 400 FT

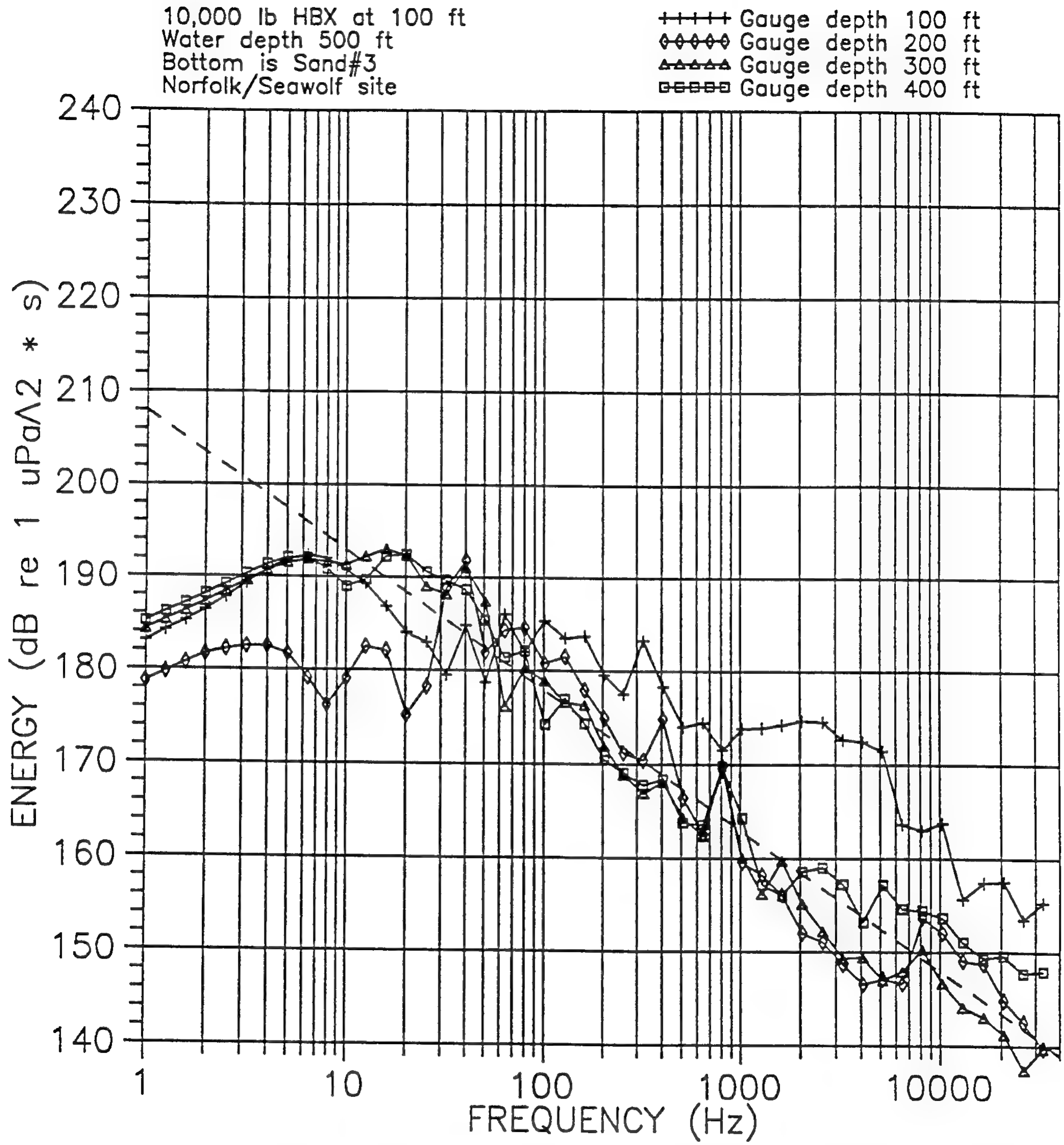

FIGURE D-4. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA
LATE JUNE-EARLY JULY; RANGE = 4 NM; MAMMAL DEPTH = 100 TO 400 FT

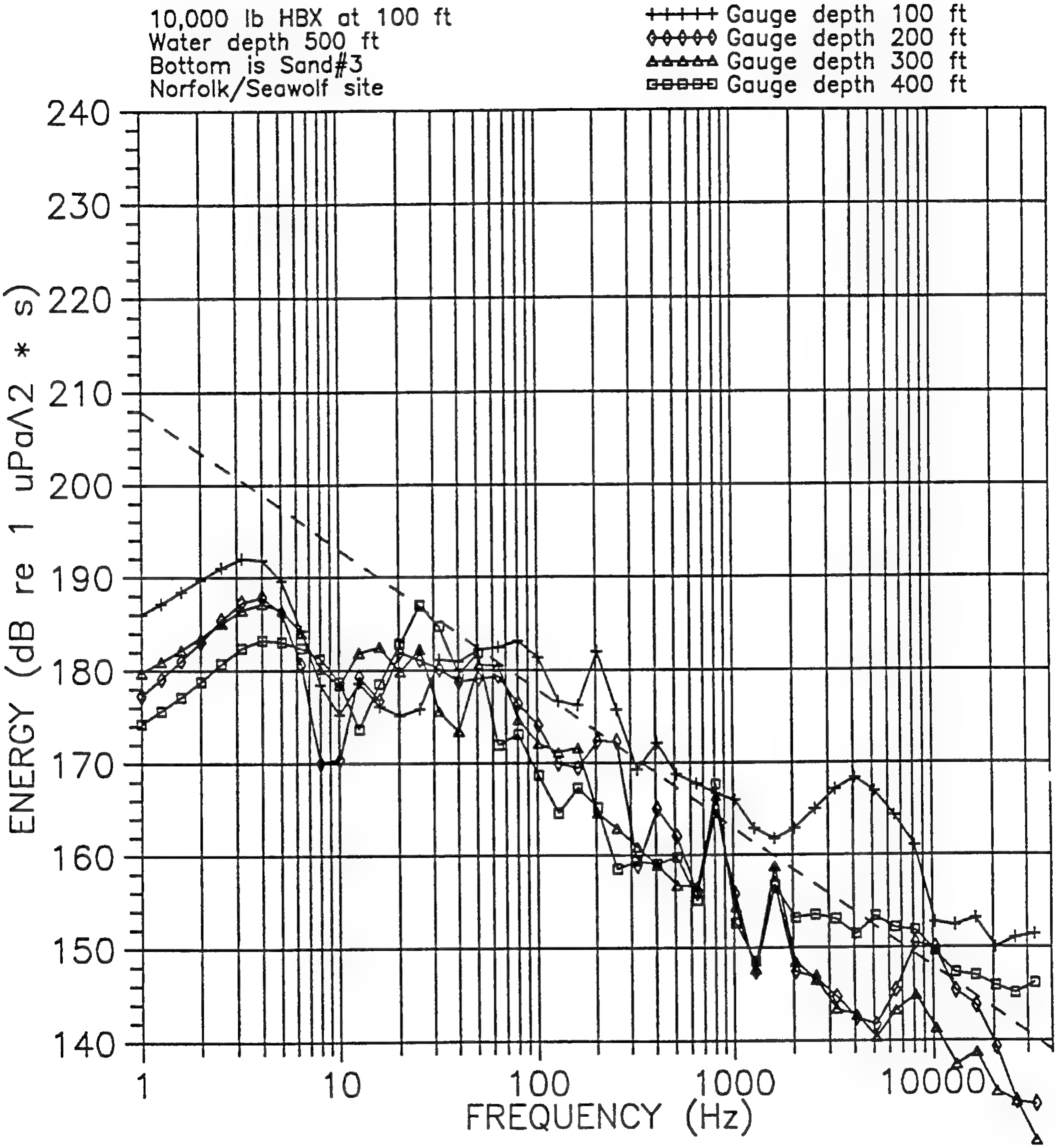

FIGURE D-5. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA
LATE JUNE-EARLY JUNE; RANGE = 6 NM; MAMMAL DEPTH = 100 TO 400 FT

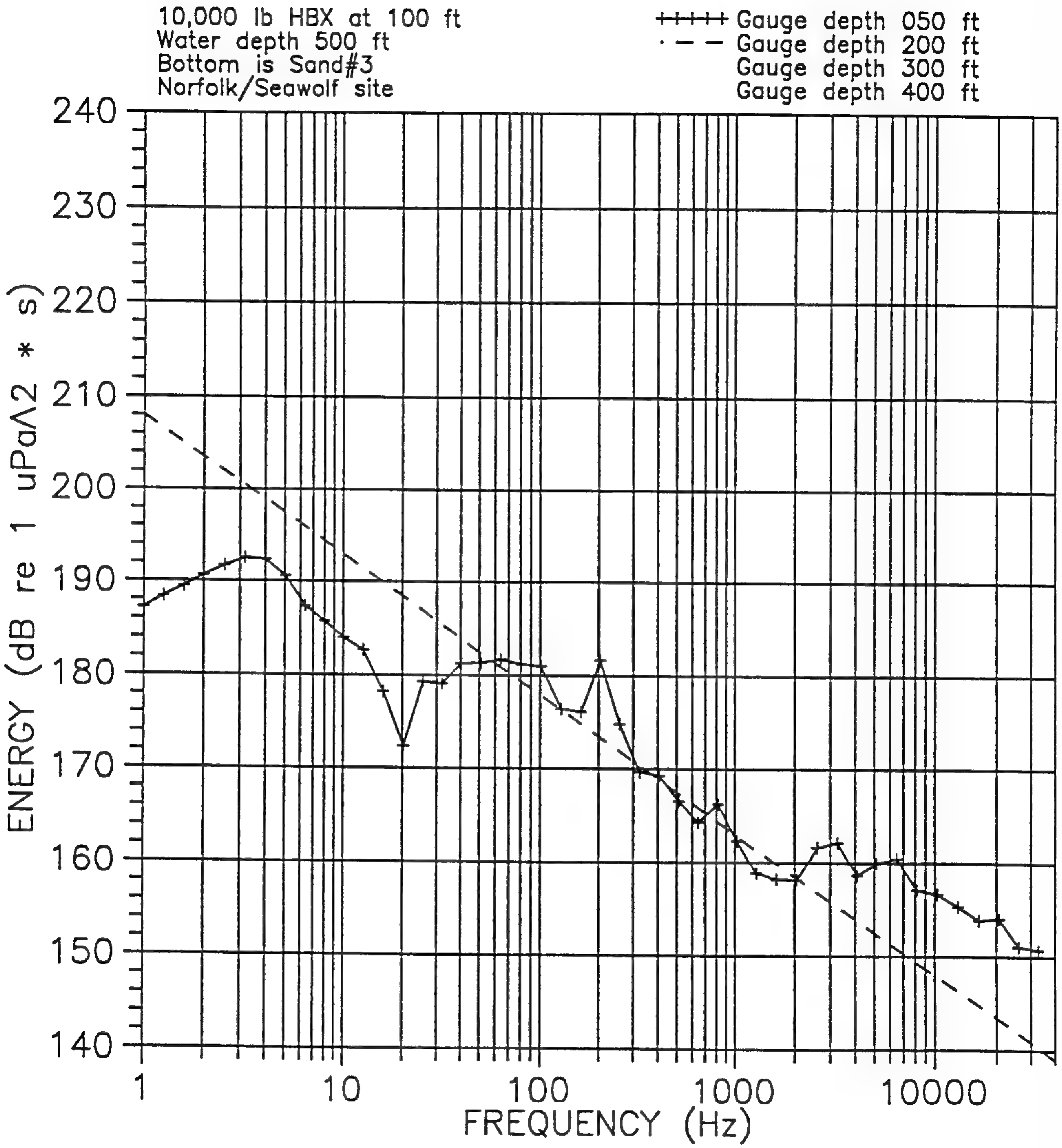

FIGURE D-6. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - NORFOLK AREA
LATE JUNE-EARLY JULY; RANGE = 6 NM; MAMMAL DEPTH = 50 FT

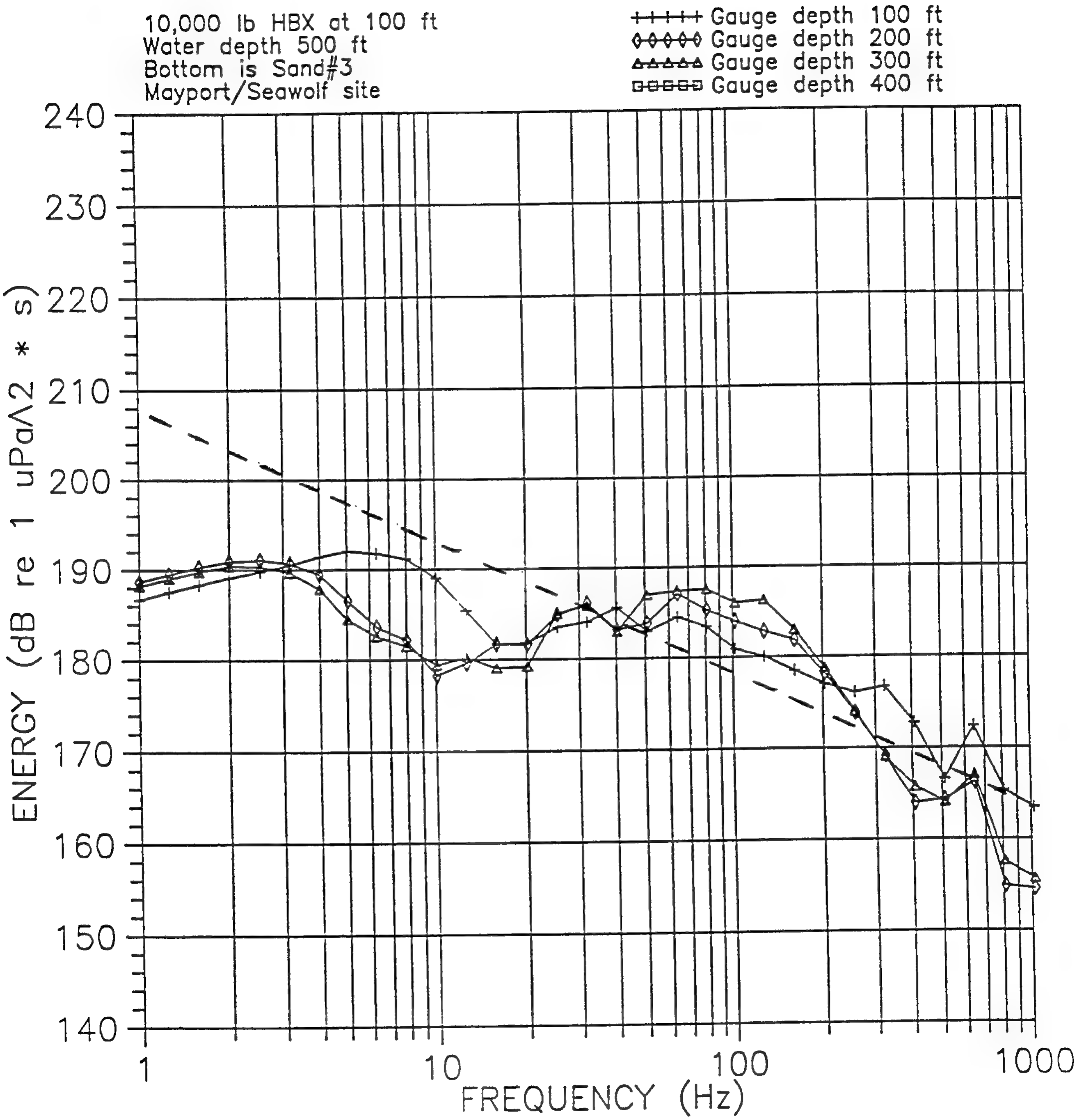

FIGURE D-7. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - MAYPORT AREA
APRIL-MAY; RANGE = 4 NM; MAMMAL DEPTH = 100 TO 400 FT

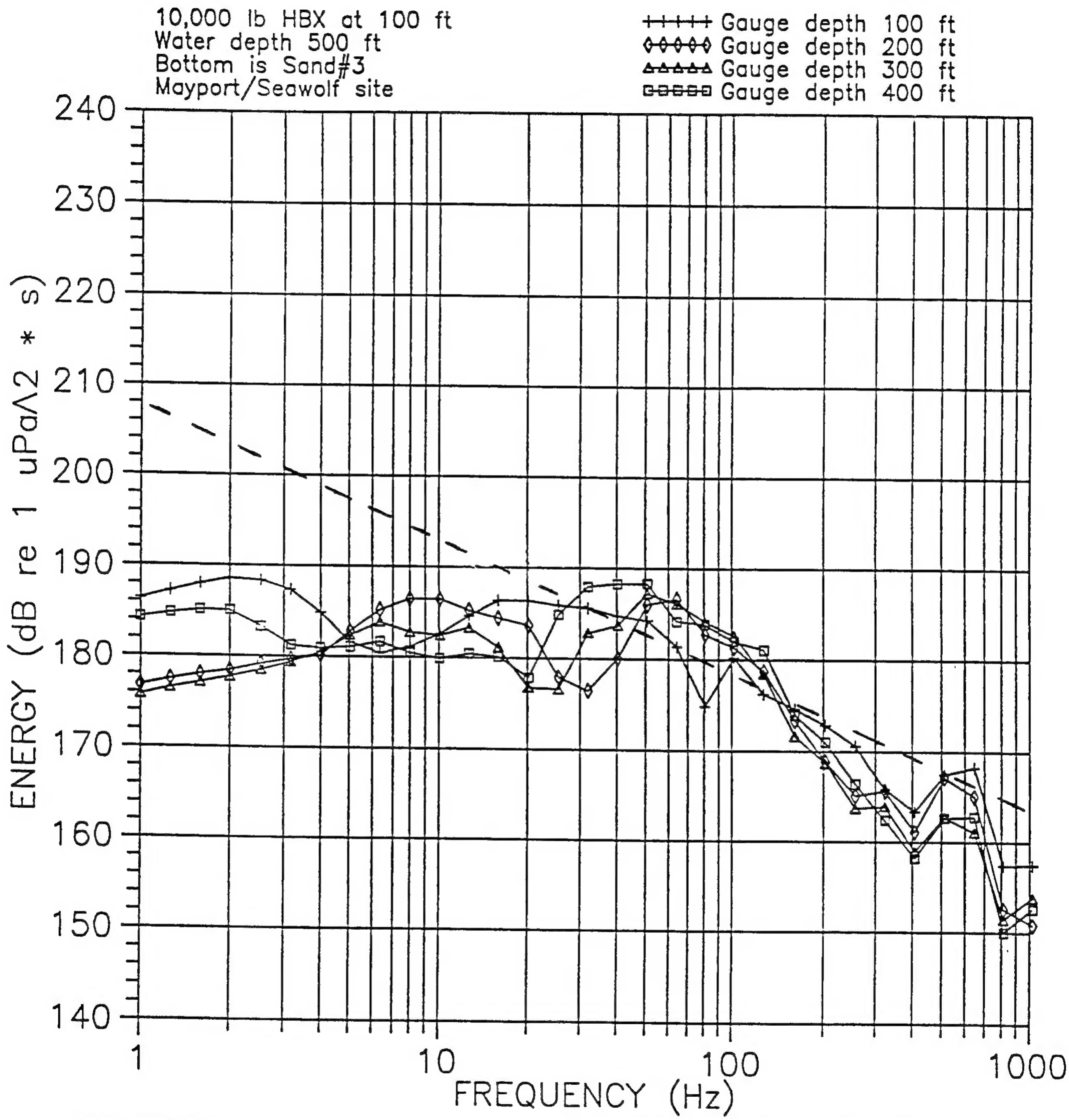

FIGURE D-8. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - MAYPORT AREA
APRIL-MAY; RANGE = 6 NM; MAMMAL DEPTH =: 100 TO 400 FT

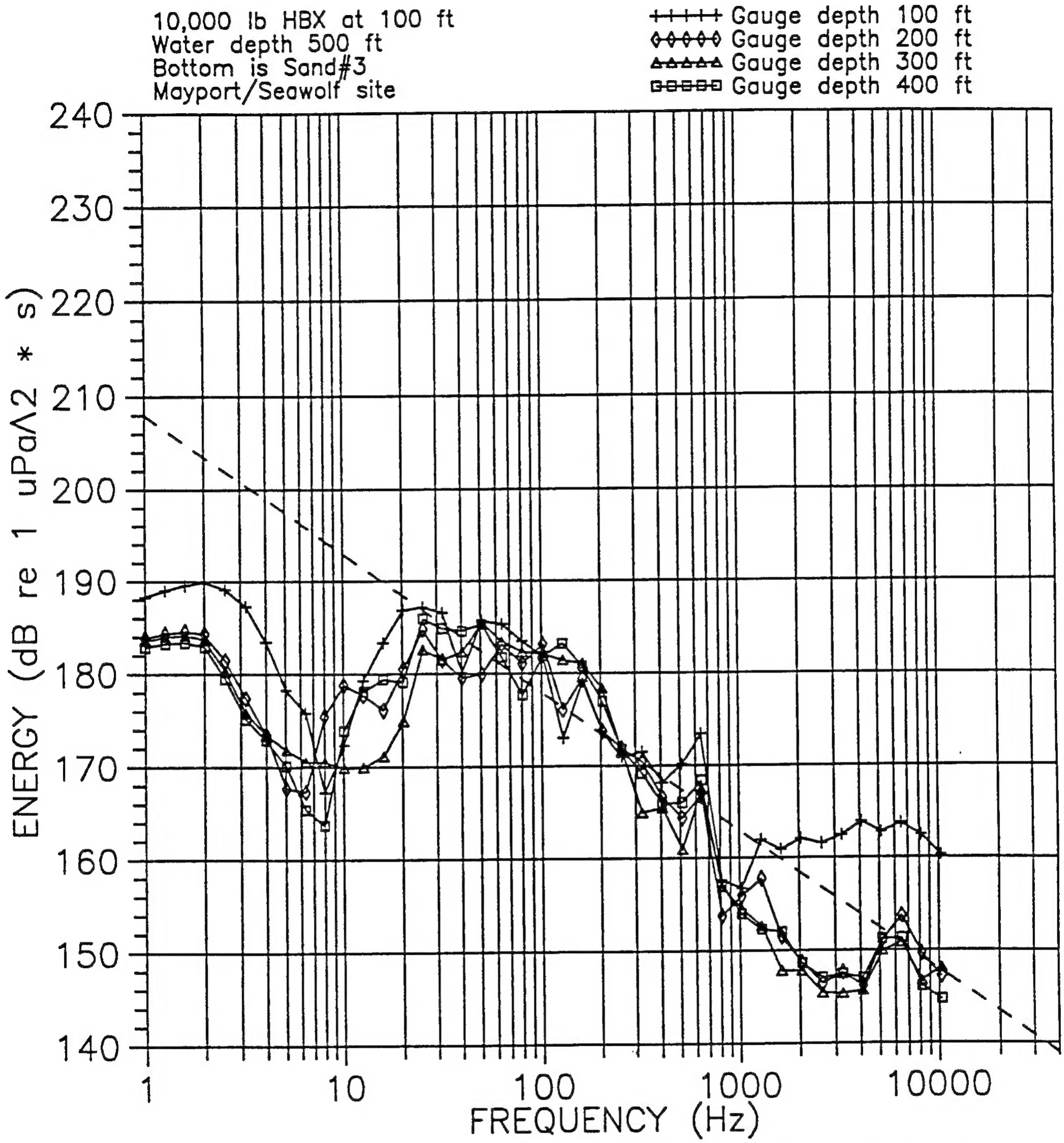

FIGURE D-9. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - MAYPORT AREA
JUNE-JULY; RANGE = 4 NM; MAMMAL DEPTH = 100 TO 400 FT

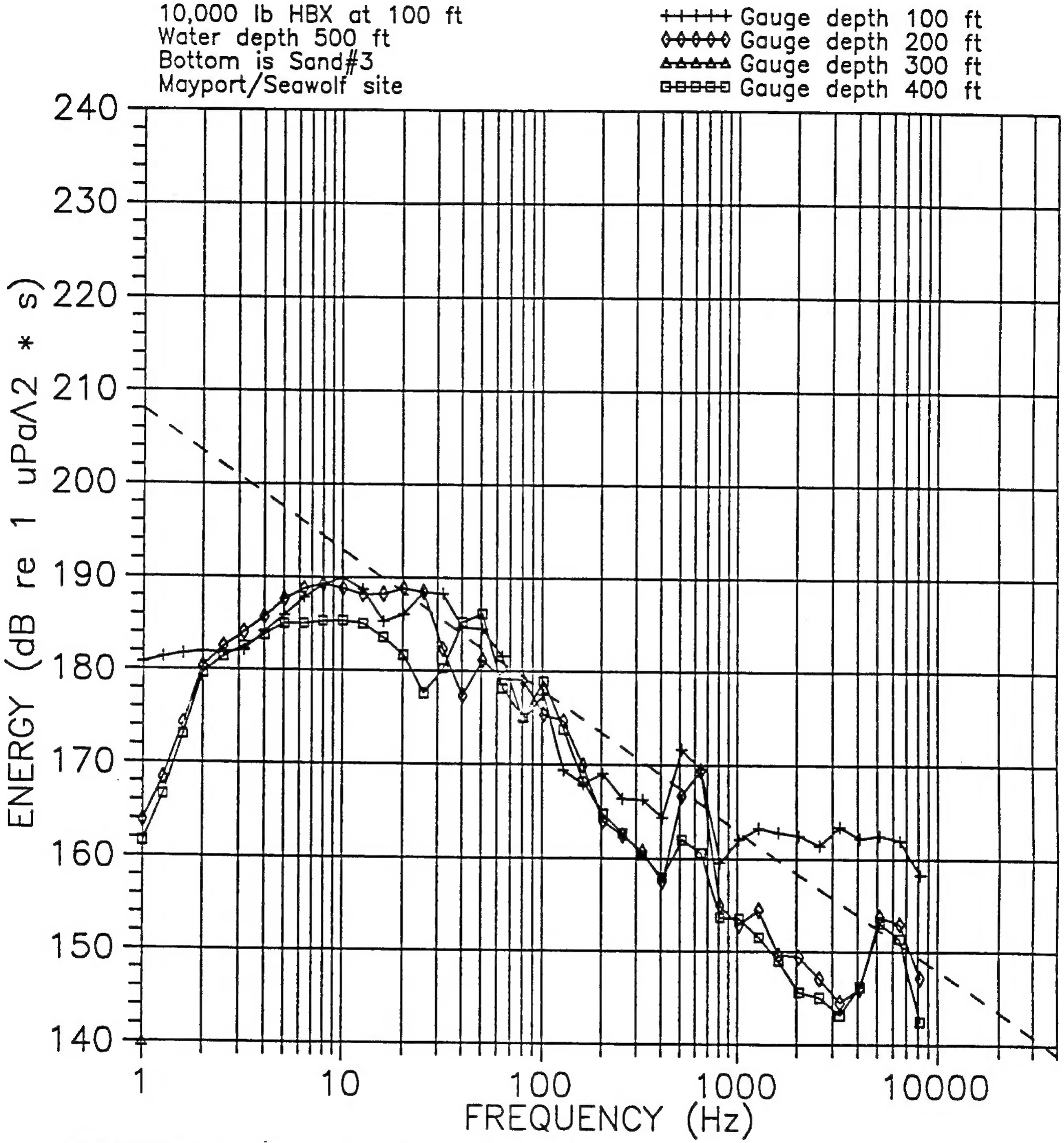

FIGURE D-10. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - MAYPORT AREA
JUNE-JULY; RANGE = 6 NM; MAMMAL DEPTH = 100 TO 400 FT

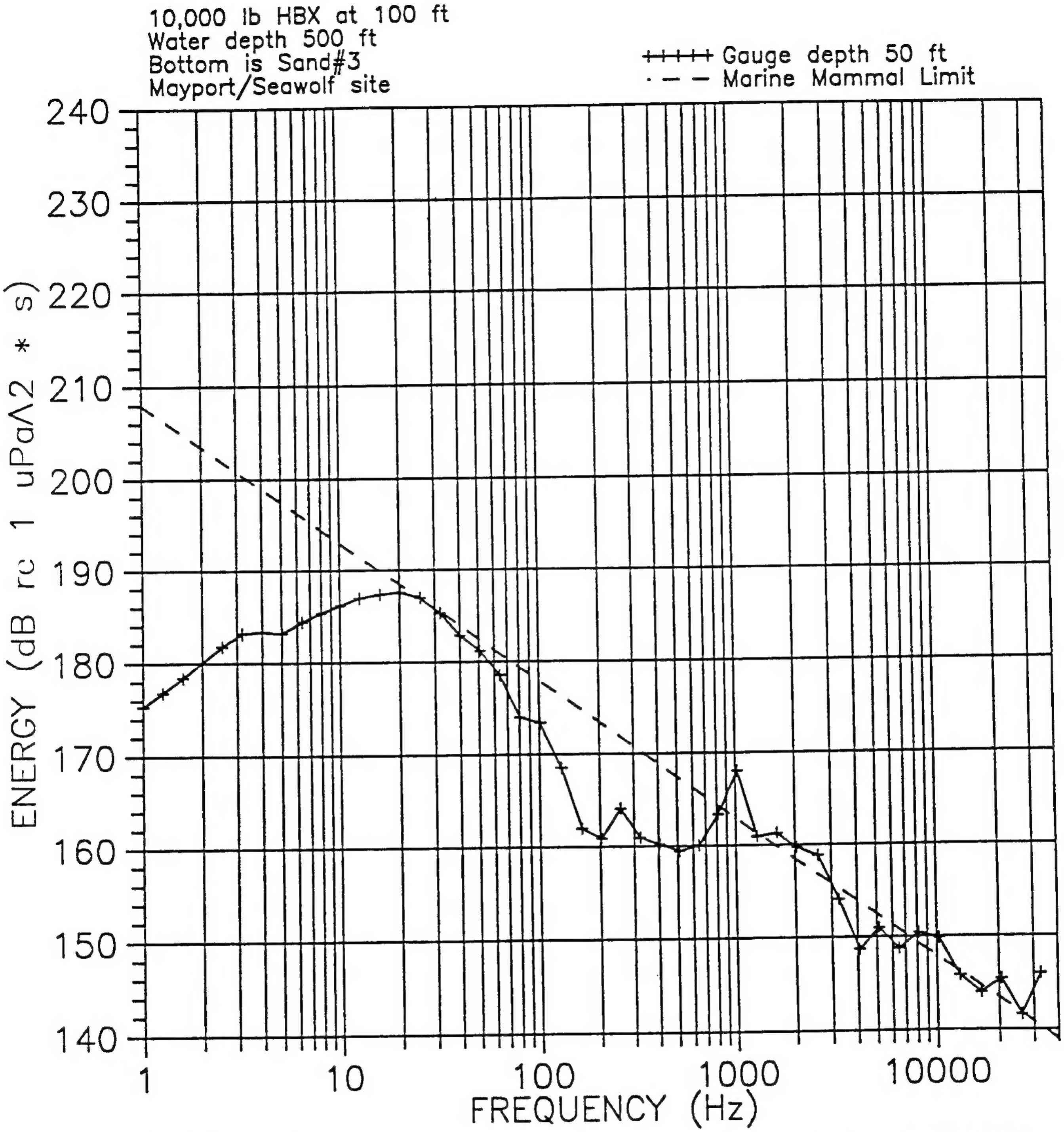

FIGURE D-11. 1/3-OCTAVE-BAND ENERGY VS FREQUENCY - MAYPORT AREA
JUNE-JULY; RANGE = 6 NM; MAMMAL DEPTH = 50 FT